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CENTRAL BANK DIGITAL CURRENCY AND THE FINANCIAL SYSTEM

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Abstract

The digitalization of money brought interest in the creation of a central bank digital currency (CBDC), a new type of digital central bank money, with its effects being predicted to be strongly felt in the financial system. This dissertation's research question aims at discussing how CBDC's might impact the various institutions in the financial system, based on a critical literature review and case study analysis of real-world cases of CBDC, the digital sand dollar and digital euro. Crucially, the design features of CBDC and the structure of the financial system into which it is introduced will largely determine its effects. The disintermediation of commercial banks via outflows of deposits to CBDC is a possibility, though central banks may impose unattractive holding limits to contain them. Banks may raise deposit rates to remain competitive, benefiting depositors, but increased reliance on expensive wholesale funding could make credit more procyclical, and reduce bank profitability. Both non-bank lending and central bank participation in financial intermediation could emerge to compensate shortfalls in bank credit. Bank runs could be facilitated by CBDC's, but a credible deposit insurance should limit incentives to run. CBDC infrastructure can be used to increase competition in payment systems, including in cross-border transactions. International use of CBDC will require cooperation among central banks to mitigate destabilizing capital flows. Finally, while existing and planned CBDC's have cautious and limiting designs, the discussions presented here provide a useful framework to anticipate the implications of CBDC's if central banks decide to relax these features in the future.

JEL codes: E4, E42, E51, E58, G21

Keywords: CBDC, Financial System, Banking Stability, Bank Runs, Money

Resumo

A digitalização da moeda gerou interesse na criação de uma moeda digital do banco central (MDBC), um novo tipo de moeda digital emitida pelo banco central, prevendo-se que os seus efeitos sejam fortemente sentidos no sistema financeiro. O objetivo de investigação desta dissertação visa discutir de que forma uma MDBC poderá impactar as várias instituições do sistema financeiro, feita com base numa revisão crítica de literatura e em estudo de casos de MDBC no mundo real, nomeadamente, o *digital sand dollar* e o euro digital. Crucialmente, as características da MDBC e a estrutura do sistema financeiro na qual é introduzida irá determinar em grande parte os seus impactos. A desintermediação dos bancos comerciais via fuga de depósitos para MDBC é uma possibilidade, mas os bancos centrais poderão impor limites pouco atrativos para contê-los. Os bancos poderão aumentar as taxas de juro nos depósitos para se manterem competitivos, beneficiando depositantes, mas maior dependência em caro financiamento por grosso poderá tornar o crédito mais pró-cíclico, e reduzir os lucros dos bancos. Quer crédito não-bancário e a participação dos bancos centrais na intermediação financeira poderão emergir para compensar diminuições no crédito bancário. Corridas aos bancos poderão ser facilitadas por uma MDBC, mas uma garantia de depósito credível deverá limitar incentivos para tal. A infraestrutura da MDBC pode ser usada para aumentar a competição no sistema de pagamentos, inclusive em transações transfronteiriças. O uso internacional da MDBC requererá cooperação entre bancos centrais de modo a mitigar fluxos de capitais desestabilizadores. Finalmente, apesar das MDBC emitidas e em preparação apresentarem *designs* cautelosos e limitantes, as discussões aqui apresentadas oferecem um enquadramento útil para antecipar as implicações da MDBC caso os bancos centrais decidam relaxar estas características no futuro.

Códigos JEL: E4, E42, E51, E58, G21

Palavras-Chave: MDBC, Sistema Financeiro, Estabilidade Bancária, Corridas aos Bancos, Moeda

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List of Acronyms

AML/CFT – Anti Money Laundering and Countering the Financing of Terrorism

ATM – Automated Teller Machine

BIS – Bank for International Settlements

BoJ – Bank of Japan

CBDC – Central Bank Digital Currency

CBoB – Central Bank of the Bahamas

CFTC – Commodity Futures Trading Commission

CPMI – Committee on Payments and Market Infrastructures

CPMI-MC – Committee on Payments and Market Infrastructures and Markets Committee

DLT – Distributed Ledger Technology

DSGE – Dynamic Stochastic General Equilibrium

ECB – European Central Bank

FSB – Financial Stability Board

GDP – Gross Domestic Product

IMF – International Monetary Fund

IT – Information Technology

KYC – Know Your Customer

LOLR – Lender of Last Resort

MMF – Money Market Fund

NBFI – Non-Bank Financial Institution

NFC – Near Field Communication

P2P – Peer-to-Peer

PoW – Proof-of-Work

PPP – Purchasing Power Parity

PSP – Payment Service Provider

RTGS – Real-Time Gross Settlement

SPACE – Study on the Payment Attitudes of Consumers in the Euro area

USDC – USD Coin

USDT – USD Tether

ZLB – Zero Lower Bound

1. Introduction

In recent decades the world has witnessed a remarkable transformation. The proliferation of information technology (IT), with its application in virtually all sectors of the economy and spheres of society, has profoundly reshaped both domains. Digitalization has gradually impacted the monetary and payments system, where physical cash (banknotes, coins) has been declining in importance. This trend was also intensified by the Covid-19 pandemic (Auer et al., 2020). At the same time, cryptocurrencies have entered the public sphere, sparking debates on the future of money.

These developments have led to discussions about central bank digital currency[1] (CBDC). This consists of a new form of central bank-issued money, complementing existing types in that it would be open to the public, like physical cash, but also digital, similarly to deposits at commercial banks. According to a 2023 survey by the Bank for International Settlements (BIS) on CBDC's and cryptocurrencies (Di Iorio et al., 2024), 94% of surveyed central banks (from a total of 86 central banks) claimed to be engaging in CBDC work. In contrast, introduced CBDC's have been small in number and solely in developing economies[2], among which are Nigeria (e-naira), the Bahamas (Digital Sand Dollar) and Jamaica (Jam-Dex). Additionally, the Eastern Caribbean Currency Union (Dcash) and Ecuador (Dinero Eletrónico) also launched CBDC's, however they were discontinued in 2024 and 2018 respectively (Arauz & Garratt, 2021; Wyss, 2022).

While definitions and taxonomy aren't uniform in the literature, we use the CBDC definition provided by Meaning et al. (2018, p. 2), considering it to be "any electronic, fiat liability of a central bank that can be used to settle payments, or as a store of value". There would be many possible ways to design a CBDC, such as whether it pays interest (Bindseil, 2019), whether the central bank directly manages the currency or indirectly, through intermediaries (Adrian & Mancini-Griffoli, 2021b), token-based versus account-based

[1] Early discussions include Koning (2014) and earlier ideas by Tobin (1985) regarding the opening central bank deposits to the public.

[2] As reported by the Atlantic Council's CBDC tracker database (Atlantic Council, n.d), https://cbdctracker.org/ .

formats (Auer & Böhme, 2020), the existence of quantitative limits (Meller & Soons, 2023), among other features which will be further discussed in section 2.3.

Though its effects would be far reaching across society, its financial system implications have been a persistent highlight in the literature. CBDC could be utilized as means of payment and store of value, presenting competition to bank deposits which perform the same functions, especially if the CBDC is designed in an especially attractive way and similarly to bank deposits, such as with interoperability with current payment systems, instant payment capabilities or if it is interest-bearing (CPMI-MC, 2018). A shift away from bank deposits to CBDC would leave commercial banks exposed, and this loss of funding may hamper their ability to lend money to households and businesses, leading to what is referred to as the disintermediation of the banking system (Group of Central Banks, 2021): as banks lose deposits, they may be forced to reduce their balance sheet, decreasing lending in order to cover these deposit outflows. Commercial banks perform a key function in the economy (aside from providing payment instruments), as their role in maturity transformation allows them to create deposits when extending loans and thus increase total money (monetary mass) in the economy, supporting firms' liquidity needs, as opposed to other non-monetary financial institutions, which simply transfer liquidity across sectors of the economy (Dyson & Hodgson, 2016). In other words, if CBDC is issued, the role of banks may be diminished, as they might be compelled to decrease the supply of credit to the economy, which would have pernicious effects on economic growth as investment and consumption depend in part on credit.

Yet, banks would not be indifferent actors and could thus respond in a variety of ways, such as increasing deposit rates to retain deposits or try to capture wholesale funding (Mancini-Griffoli et al., 2018), with gains for depositors from increased competition. Another scenario may be an increased role in central bank funding to cover deposit outflows (Brunnermeier & Niepelt, 2019), though this option requires an expansion in the size of the balance sheet of the central bank, implying increased responsibilities for credit allocation, which goes beyond the traditional mandate of the central bank (CPMI-MC, 2018).

Moreover, due to being central bank money and thus a risk-free asset, fears have been expressed that the new payment instrument would incentivize and deepen bank runs, destabilizing the financial system (Ahnert et al., 2024). These "digital" bank runs (since they would take place through a digital transfer of bank deposits to CBDC) may be more

disruptive than previous ones, since digital bank accounts enable immediate transfers of deposits at a click of a button (Kumhof & Noone, 2021). While this is already technically feasible in runs from one bank to another, the presence of CBDC would allow an aggregate run from bank deposits (i.e. from all banks) to CBDC (Mersch, 2017). We can thus distinguish between a slow, somewhat manageable disintermediation, and a more crisis-like scenario where banks lose their deposits extremely quickly, or as Bidder et al. (2024) put it, "disintermediating fast and slow".

Furthermore, a CBDC may impact the financial system beyond banks. A smaller role for commercial banks in credit extension may open the way for greater non-bank lending in the economy, with new benefits and risks to the economy. In addition, pressures to run to CBDC may also stress certain investment funds if faith is lost in its management or its assets, with clients redeeming their shares ultimately for CBDC (Infante et al., 2024). Moreover, a CBDC that is available across borders may increase international capital flows, resulting in exchange rate volatility (Dyson & Hodgson, 2016), and may accelerate currency substitution in countries in economies with weak currencies (Popescu, 2022).

The research question of this dissertation will therefore be, how might CBDC's impact the financial system? This is a pressing question that requires an answer, as the decision to issue CBDC must be made on a firm understanding of its consequences, if its rollout is done in a proper and safe way, and policymakers need to understand the risks that the financial system may face from this new type of money and how it might change because of it. The growing interest of central banks in CBDC's (Di Iorio et al., 2024) makes this a relevant research topic. It looks to add to the existing literature by offering insights into how CBDC could affect the financial system. Given the discretionary nature of CBDC design, in that central banks may choose to adopt different design characteristics or change them in the future, this discussion will naturally remain open-ended.

Hitherto only non-advanced economies have introduced CBDC's, and thus there is no empirical evidence available on the impact of CBDC's on the financial system in advanced economies. Thus, the methodology of this dissertation will consist, on the one hand, of a critical literature review, based on the relevant academic literature and on publications by central banks and other relevant institutions, and on the other hand, case study analysis, which will include already issued CBDC's, namely the Bahamian Digital Sand Dollar, and as CBDC's have only been introduced in developing nations, we will analyse CBDC's in

development and pilot stage among more advanced economies, namely the euro area's digital euro.

The rest of the dissertation is organized as follows: in chapter 2 we discuss the evolution and digitalization of money, including cryptocurrencies and CBDC. Chapter 3 discusses the problem of disintermediation of banks, including balance sheet effects, impact on credit supply and bank funding, and the banking sector more generally, as well as the possible role of the central bank. Chapter 4 discusses bank run issues related to CBDC. In Chapter 5 other financial system consequences will be discussed, including the possible role of non-bank lending, CBDC's impact on other financial institutions and financial markets, and its cross-border use. Chapter 6 features the case study portion of the dissertation looking at already introduced CBDC's and ones in development, followed by a conclusion.

2. The evolution of money: Digitalization, cryptocurrency and CBDC

To understand the run up to CBDC and contextualise the discussion surrounding it, we must first understand some of the technological changes to money and payments systems that have occurred in recent history. This will include the digitalization of commercial bank money, and the rise and technology behind cryptocurrencies. We conclude with an introduction to the possible designs and features of a CBDC. Because it is digital, understanding the technology behind CBDC is critical to understand it and its impact: indeed, due to its electronic nature, discussion of CBDC may sometimes appear as "otherworldly" to economists (Meaning et al., 2018, p. 2), as they may not be familiar with these topics.

2.1 The digitalization of money and payments

Money today is held primarily electronically in accounts at commercial banks. This has been a shift from the past where money was held physically in the form of banknotes or coins which has been made possible by the proliferation of IT.

The influence of IT in the banking sector can be observed in the various technological developments in recent decades. The introduction of the automatic teller machines (ATM) allowed bank customers to withdraw and deposit money with their cards, check balances as well as make transactions and payments, eliminating the need for bank tellers and substantially reducing the number of bank branches. The declining cost of personal computers and smartphones allowed account holders to make transactions and pay bills from the comfort of their home, automatically through direct debit, and anywhere through home banking, by remotely connecting to the bank's server (Mishkin & Eakins, 2024). Indeed, one impact of the digitalization of financial services is the automatization of business processes, resulting in less physical components and human interaction in the provision of financial services (Puschmann, 2017), which allowed financial sector firms to increase both profitability (by cutting costs) and increase customer convenience. These

technological developments have resulted in the decreased importance of bank notes and coins in the payments systems, replaced by digital alternatives such as bank deposits (see Figure 1[3]).

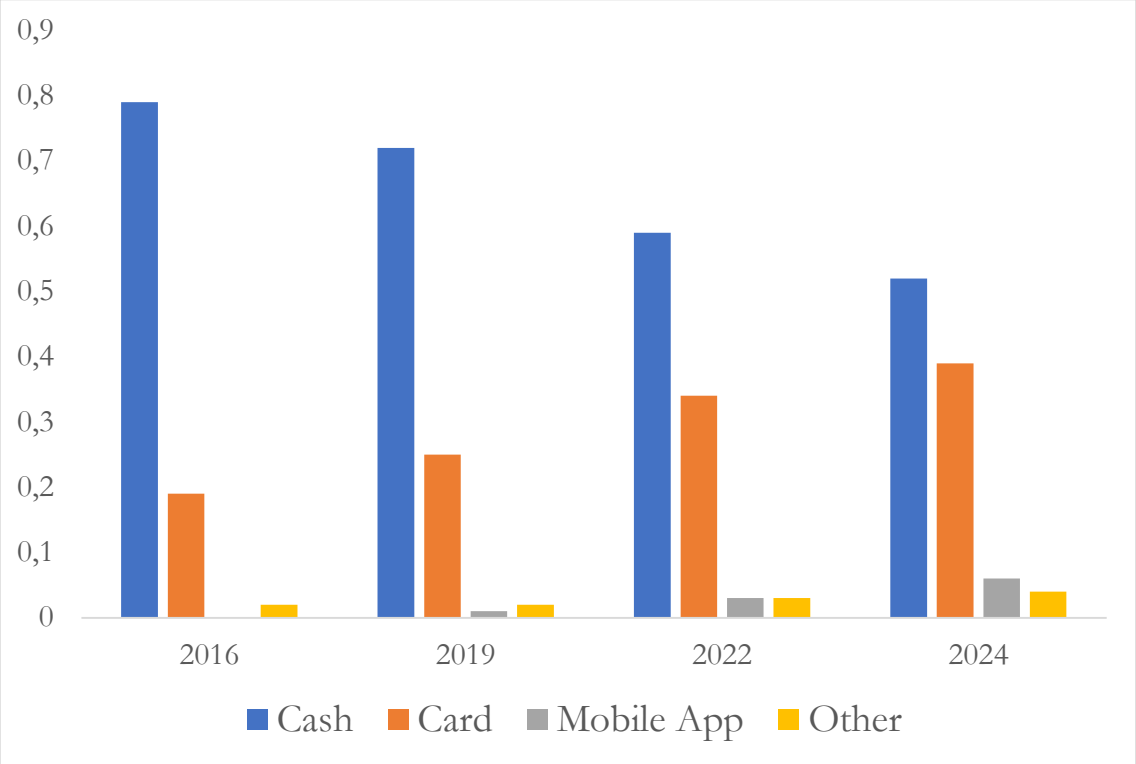

Figure 1 *- Evolution of the portion of cash, cards (debit, credit and prepaid) and mobile app payments in total payments, by number of payments (volume) in the Euro Area, 2016 - 2024.*

This digitalization is also reflected in the rise of fintech[4], with start-ups and big tech firms progressively entering the finance sector, innovating and creating competition in a field (such as in payments, deposit and lending services) traditionally dominated by banks: "fintech encompasses innovative financial solutions enabled by IT and, in addition, is often used for start-up companies who deliver those solutions, although it also includes the incumbent financial services providers like banks and insurers" (Puschmann, 2017, p. 70). Some applications of Fintech include lending services, such as peer-to-peer (P2P) and online lending (for example, firms such as SoFi), the utilization of Big Data and the implementation

[3] The data from the chart was adapted from chart 4 of the Study on the payment attitudes of consumers in the euro area (SPACE) 2024 (ECBb, 2024), https://www.ecb.europa.eu/stats/ecb_surveys/space/html/ecb.space2024~19d46f0f17.en.html , accessed 22nd March 2025. The same downward trend for cash is observed when considering the value of payments, with the portion of cash being lower compared to number of payments.

[4] Fintech is an amalgamation of the words finance and technology. See Giglio (2021) for a review of fintech over time.

of blockchain technology in financial services (Goldstein et al., 2019), the latter of which is the main building block behind cryptocurrencies which we will discuss in the next section (2.3.2). Also included are fully digital banks[5], such as Revolut, which do not have a physical presence (e.g. branches) and instead manage their services via smartphone apps, with a focus on a strong user interface, offering little to no fees and providing a variety of services such as basic demand deposits, debit cards, saving and spending tracking, high yield savings accounts, cash advances, P2P[6] payments, among other features (Bradford, 2020).

More recently in payment services, we have seen the proliferation of contactless payments, where payers can pay without swiping or even inserting a debit or credit card, thanks to near-field communication (NFC), a technology that allows electronic devices to communicate when they are in close proximity (Beck, 2024). It has been combined with mobile payment services (e.g. Apple Pay), allowing users to pay with their smartphones by adding their card details to the service, eliminating the need for physical debit/credit cards.

The rise of e-commerce, where customers can buy goods and services over the internet, has made it not just convenient, but rather a necessity, to adopt digital forms of money, since payment with physical cash becomes impossible due to its digital nature, compelling anyone that wishes to take part in e-commerce to adopt electronic-based money. This form of commerce mirrors another trend of the digital economy, namely the rise of "Big Tech" companies, such as Amazon, Facebook, Alibaba, among others, which provide digital platforms to buy and sell goods, acting as intermediaries between buyers and sellers, and benefitting from strong network effects (Ahnert et al., 2024).

As all these developments decreased the demand for physical cash, increasing the importance of digital money, CBDC's have been seen as the answer by central banks to maintain the relevance and accessibility of central bank money to the public: as reported by the same BIS survey (Di Iorio et al., 2024), one of central banks' main motivations for the issuance of CBDC is the preservation of the role of central bank money in the economy, as the credible promise to exchange private money for central bank money at par is considered crucial to maintain financial stability (Adrian & Mancini-Griffoli, 2021a; Panetta, 2021). A

[5] Also known as neobanks.

[6] Transactions may be conducted in a decentralized fashion, directly from P2P without a third party or in a centralized fashion with a third party acting as an intermediary between two agents (CPMI-MC, 2018).

CBDC would be made available to be used in digital payments, thus extending the presence of central bank money into digital platforms and e-commerce. Moreover, CBDC is seen as a way to provide competition to private payment providers (including banks) which may charge rents due to their monopolistic position and capability to collect data on digital transactions (Ahnert et al., 2022; Garratt & Van Oordt, 2021).

2.2 Cryptocurrencies and Stablecoins

Cryptocurrencies, such as bitcoin or ethereum, have also given impulse to discussions on the nature and future of money, not so much due to their digital nature, but rather due to their ability to conduct transactions without a trusted intermediary to monitor and validate them (Broadbent, 2016), through the use of the novel distributed ledger technology (DLT). The most famous type of DLT is blockchain, which is used by almost all major cryptocurrencies. The "crypto" from the word cryptocurrency refers to the use of cryptographic techniques associated with DLT, as we will see below. A Financial Stability Board (FSB) report provides the following the definition: "Crypto-assets (…) are a type of private asset that depends primarily on cryptography and DLT as part of its perceived or inherent value." (FSB, 2018, p. 3). Compared to a standard centralized ledger of a bank, with its own secure computer servers in which a central ledger keeps track of all the outstanding balances and transactions, controlled and updated solely by the system administrator, a trusted intermediator, in a DLT system a decentralized ledger is updated via consensus over a network of computers[7].

Bitcoin[8] was the first cryptocurrency to come into existence in 2009 (Nakamoto, 2008), and its early popularity and usage was related to libertarian views on political economy (Andreessen, 2014), viewing bitcoin as an instrument to bypass financial intermediaries and governments (Ray, 2024), precisely by allowing transactions without an intermediary.

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[7] Note that it is possible to have the same centralized ledger multiplied (or distributed) over many physical locations for precautionary reasons (Auer & Böhme, 2020), though this isn't the same as distributed ledger.

[8] As of 28th of March 2025, one Bitcoin is worth around €77,500, up 19.7% from the previous year, with a market cap of € 1.5 trillion according to the crypto exchange Coinbase (Coinbase, n.d. -a), https://www.coinbase.com/pt-pt/price/bitcoin , accessed 28th March 2025.

Böhme et al. (2015) describe the bitcoin protocol for a non-technical audience: with blockchain technology, the most prominent form of DLT, transactions are recorded in a distributed ledger referred to as blockchain, which is maintained and updated by users across a network of geographically dispersed computers (hence "distributed" ledger technology), eliminating the requirement of a trusted intermediary (e.g. a bank). In other words, each user (node) in the network helps maintain and update its own copy of the ledger which contains all transactions in the bitcoin network. To maintain the privacy of the user, transactions are conducted with a public-private key pair (a cryptography technique, hence "crypto"), with the public key acting as a public identifier (akin to an email address and thus shared with other users to be able to receive bitcoin, without revealing anything about their identity) and a private key that authorizes transactions. A batch of transactions is called a block which is added to previous blocks of previous transactions (hence blockchain). To assure the integrity of the system, such that nobody adds fraudulent transactions to the block, "miners" (since they work on blocks) need to use considerable computational power to solve complex mathematical puzzles that require non-trivial electricity demands[9] to approve the new blocks before adding them to the chain, for which they get a reward (bitcoins). This validation method is known as "Proof-of-Work" (PoW), and it allows decentralized P2P transactions without intermediaries. However, if a user loses or has their private keys stolen, they can permanently lose their funds.

Privacy concerns were one of the original motivations for the usage of bitcoin, due to its cryptographic features, but became widely used for transactions in illegal activities, such as drug trafficking and gambling. A study in 2019 provides an estimate of $76 billion of illicit activities conducted every year with bitcoin, with around a quarter of its users participating in it (Foley et al., 2019), though the trend shows that this proportion decreased as crypto became more mainstream. In addition, in spite of its ethos of decentralization, many economic forces (such as economies of scale) push bitcoin towards centralized players (Böhme et al., 2015), such as currency exchanges (that exchange fiat currency for bitcoin), digital wallet providers (custodians to help guard private keys) and mining pools (when miners combine computing power to solve a puzzle, dividing the rewards), which can be

[9] Bitcoin's high electricity consumption, necessary to validate transactions, has been subject to public criticism (Huang et al., 2021).

subject to regulation by authorities. Famous exchanges and wallet providers include Binance and Coinbase.

While the technology underlying bitcoin shows promise, it is unclear whether it will ever be considered a form of money. Money is a generally accepted means of payment, with other desirable functions being its use as a store of value, unit of account and a standard of deferred payment. Yet, as pointed out by Yermack (2024), it is clear that bitcoin, and by extension other crypto, cannot be considered a form of money (at least not yet): for example, it is extremely volatile in value undermining it as a means of payment and it is virtually not used as a denomination in any contracts or debt[10], and its security vulnerabilities (e.g. stealing of keys) make it a not particularly safe asset to hold. Indeed, it is unsurprising that cryptocurrencies are now commonly referred to as "crypto assets" (FSB, 2018), emphasizing that it is more of an investment than a secure means of payment.

As cryptocurrencies suffer from excessive volatility, hampering it as a means of payment, stablecoins emerged to overcome this problem by offering a peg to non-crypto assets (Arner et al., 2020), usually to fiat currencies such as the dollar (but also other assets such as gold), which include USDT or USD Coin (USDC). Baughman et al. (2022) provide an overview of stablecoins: some stablecoin issuers may be thought of as currency boards, in that to maintain the peg to a given currency, they must hold that currency in a reserve, which is referred to as a "stabilization mechanism". Stablecoins may be divided into 2 categories: collateralized and uncollateralized (or algorithmic), that is, on the one hand, those whose value is backed by assets, or, on the other hand, those whose value is maintained through a protocol that automatically increases or decreases supply according to demand[11], respectively. Collateralized stablecoins may be divided into 2 other subcategories: on-chain, when the assets backing them are other cryptocurrencies and thus can be recorded on a blockchain, and off-chain, which are backed by bank deposits or treasury bonds and hence need a custodian to hold them until they are redeemed. Off-chain collateralized stablecoins, such as USDC or USDT, have by far the greatest market cap[12], and are created and managed

[10] In fact, its value is appraised through the bitcoin-dollar (or other national currencies) exchange rate, demonstrating the unit of account role of traditional fiat currencies.

[11] In other words, if demand increases, supply is created decreasing its price, and if there is too little demand, supply is destroyed increasing the price, maintaining the equilibrium and the exchange rate.

[12] For example, as of April 1st, 2025, USDC (Circle) has a market cap of $55 billion (Coinbase, n.d. -b), https://www.coinbase.com/en-pt/price/usdc .

by private firms (Circle and Tether, respectively), which are the custodians of the reserves and mint the currency. Finally, as they are considered cryptocurrencies, transfers of these coins are also recorded and validated on a blockchain, however, in off-chain stablecoins, the redemption of coins for fiat currencies is done outside the blockchain via the custodian.

In practice, however, there are some caveats. First, stablecoins will usually not actually be pegged 1-to-1 with the other currency, but may be worth slightly more or less, and they do in fact fluctuate, albeit slightly and significantly less than traditional cryptocurrencies. Furthermore, in the case of off-chain stablecoins, since the supply is managed by a central actor, there is always the possibility of fraud, that there isn't 100% backing of the currency, and thus there is no guarantee that the peg will hold. For example, Tether (USDT) was fined $42.5 million among other reasons for maintaining its reserves of dollars only 27.6% of the days over a period of twenty six months between 2016 and 2018 (CFTC, 2021). Moreover, maintaining the peg on all types of stablecoins is dependent on the belief by its users that the peg will be maintained (Huang et al., 2023), and if not there is an incentive by users to sell their coins, increasingly below their value, resulting in fire sales, and such lack of confidence may be self-fulfilling. This may arise from a drop in the value of the assets that back it or a loss of faith in the custodian or the protocol (Baughman et al., 2022).

In 2019, Facebook, along with other members of a consortium such as PayPal, Visa and Spotify, tried to launch their own private stablecoin initially called Libra (Libra Association, 2019), later renamed Diem, leveraging their digital platforms such as Facebook Market Place (e-commerce) to incentivize the use of the currency, however this proposal faced backlash by many regulators including central banks (Arner et al., 2020), with the project being abandoned in 2022. Nevertheless, the attempt itself intensified discussions on CBDC due to the potential of stablecoins to erode the monetary sovereignty of central banks, as users of these digital platforms would have used these stablecoins rather than central bank money to conduct transactions.

DLT is relevant to the discussion on CBDC's, as we will see in the next section, as central banks have discussed the application of the technology in a CBDC.

2.3 CBDC: Design and features

The literature on CBDC contains a variety of approaches to classify this new form of money, whether by comparing the different potential characteristics CBDC (Auer & Böhme, 2020; Kiff et al., 2020), existing forms of money to CBDC (Adrian & Mancini-Griffoli, 2021b; Bjerg, 2017) or both (Bech & Garratt, 2017; CPMI-MC, 2018). Studies on the impacts of CBDC's may assume different characteristics, either explicitly or implicitly. For instance, some assume that CBDCs are non-interest-bearing, while in others assume they are remunerated. There are even conflicting definitions of what a CBDC is[13] and the use of different terminology[14]. While terminology is to some extent arbitrary, with divergences in taxonomy reflecting the emerging nature of the field (since CBDC's are a relatively new phenomenon), a proper classification system of the different forms and characteristics that CBDC may take up is crucial to have a firm understanding of it.

However, different presuppositions and diversity of terminology employed can cause confusion to the reader who is not fully familiarized with the literature. Moreover, as we will see ahead, different design characteristics of CBDC could have specific effects on the financial system, so understanding the nature of each design will also help to understand their impacts.

Thus, the goal of this section is to present an overview of the different features of CBDC that the central bank could implement, with the goal of clarifying the reader as to both the nature and the consequences of different designs of CBDC. The design features we will discuss will be the direct and indirect approach to CBDC, wholesale versus retail concepts and the use of DLT, token-based versus account-based CBDC, and the possibility of interest payments (remuneration) and quantitative limits.

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[13] For example, Adrian and Mancini-Griffoli (2021b) propose a (synthetic) CBDC, where private companies issue and manage digital currency that is fully backed by central bank money, but this directly conflicts with other definitions of CBDC that consider it to be solely a claim on the central bank (Group of Central Banks, 2020).

[14] Bech and Garratt (2017) refer to token-based CBDC as central bank cryptocurrencies (CBCC) and use the term "Deposited Currency Accounts" account to refer to account-based CBDC, contrasting, for instance, with Auer and Böhme (2020) and the terminology used in this dissertation. Mersch (2017) doesn't use the term CBDC, but rather "digital base money".

2.3.1 CBDC: Direct or indirect approach?

The difference between direct or indirect CBDC relates to the extent of participation of the central bank in managing the CBDC system, or the "distribution channel used by the central bank" to deliver CBDC to the public, as Engert and Fung (2017, p. 10) put it. I take a similar approach to Dyson and Hodgson (2016) by considering a direct CBDC to be a situation where the central bank directly manages and oversees transactions and client onboarding more generally, and an indirect CBDC where one or multiple private sector intermediaries, potentially banks, handle retail management, but with funds still remaining in possession of the central bank (otherwise it could not be considered CBDC). Crucially, if there were for instance financial problems with the underlying intermediary, households' CBDC would be safe because they would not be part of the intermediary's balance sheet, they would be claims on the central bank, as per our definition in the introduction. Retail management would include responsibilities such as customer service, home and mobile banking services with the appropriate user interface, know your customer (KYC) and anti-money laundering and countering financing of terrorism (AML/CFT) measures, among other tasks.

An indirect approach would likely be more amenable to central banks, as hands-on client management is outside the expertise and traditional functions of the central bank and would thus entail new and significant costs. Moreover, various private sector payment providers (not least banks) already have the experience and capability to perform these tasks. Auer and Böhme (2020) point out that one of the difficulties would be the building and management of a reliable and speedy payment network, designed to operate at significant scale (with multiple small transactions), and prepared to deal with connectivity outages, which is outside central banks' current capacities, although a direct approach would benefit from the scheme's simplicity. Moreover, in a direct approach, operational problems such as connectivity outages may be blamed on the central bank rather than private operators, potentially hurting the central bank's reputation (Ahnert et al., 2024).

2.3.2 Wholesale vs. Retail CBDC and the use of DLT

Retail CBDC refers to the use of CBDC by the wider public and businesses, to be used for daily, namely small value transactions. Conversely, a wholesale CBDC would be a CBDC only accessible to select financial institutions to settle transactions between them in a wholesale fashion[15]. However, some of the literature seems to refer to wholesale CBDC in the context of the application of DLT technology and tokenisation (see section 2.2) to the current reserve system[16], as well as to central bank pilots that test this technology[17] with an interest to update the Real-Time Gross Settlement (RTGS) scheme, which is considered to be falling behind and unmodernized (Bech & Garratt, 2017). Reasons to implement DLT include to retain relevance in a scenario where private actors choose to adopt some forms of DLT technology (Panetta, 2022), which, as exemplified by Diem, remains a possibility.

2.3.3 Token-based vs. account-based CBDC

A CBDC, as well as other forms of money, can be classified into account-based or token-based. An account-based money is a familiar format, as it would parallel bank accounts in commercial banks, where the account of the payer is debited, and the account of the payee is credited when a transaction takes place. A token-based form is similar to physical cash and cryptocurrency, as both are tokens. A token works by transferring an object, which contains value, from one person to the other, with no account being involved (Mersch, 2017). In a token-based CBDC, payments would be made by a transfer of digital tokens from one digital wallet to another, mirroring cryptocurrencies, also digital tokens. Likewise with fiat money, where banknotes or coins (i.e. tokens) are exchanged from one person to another (from one wallet to another), no account involved[18].

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[15] CPMI-MC (2018) distinguishes between retail and wholesale transactions by their low and high value, respectively (see footnote 7).

[16] Including Bech and Garratt (2017), CPMI-MC (2018), de Galhau (2023) and Ahnert et al. (2024).

[17] See for example project Jasper by the Bank of Canada (Payments Canada et al., 2017) and project Stella by the European Central Bank and Bank of Japan (ECB & BoJ, 2018).

[18] In a world of digital tokens however, transactions would still be registered on a ledger (whether a centralised or distributed one (DLT)), as opposed to physical cash transactions.

Since token systems operate on the transfer of some kind of payment object (token), they rely on the ability to verify that said token is valid, whereas account systems use identification to correctly identify payer and payee to approve transactions (CPMI-MC, 2018; Kahn & Roberds, 2009): for example, in token systems, the physical cash used to pay may be counterfeit and the problem behind private digital currencies, which cryptocurrencies sought to circumvent, is whether a token is fraudulent or has already been spent, i.e. double-spending (Ali et al., 2014), while in account systems malicious actors may obtain personal information to transfer funds out of accounts.

An account system would likely be more straightforward to the public due to the ubiquity of bank accounts, as opposed to digital tokens. Moreover, if a token CBDC were to function with a public-private key pair to approve transactions, losing or theft of keys would result in a loss of funds (Engert & Fung, 2017), similarly to bitcoin and other crypto (though physical cash also contains risk of theft). In contrast, since a token system would not be tied to identity, it could stand to offer greater anonymity (Auer & Böhme, 2020), similarly to physical cash: once tokens enter into circulation, the central bank would be unaware of who holds them, just like with bank notes and coins (Bindseil, 2019). Realistically, central banks would want to implement strong AML/CFT measures when planning CBDC's making it less likely that they will follow this design, nevertheless they could make available a token-based variant with quantitative limits, including for tourists, alongside with an account-based format, to leave room for (some) privacy.

2.3.4 Remuneration and holding limits

Remuneration of CBDC, namely paying interest on balances, is also a possible design option. Interest rates on CBDC may be used to manage the demand for it: if demand increases too much, interest rates can be decreased to make CBDC less attractive and vice-versa. But an interest-bearing CBDC would also have monetary policy implications. For example, the interest rate on CBDC may create a floor for interest rates both for money markets and retail deposits: no money market participant would accept extending loans at a rate lower than the rate of interest on CBDC, and commercial banks would have no choice than to raise deposit rates lest their clients easily switch to CBDC deposits if these paid higher

rates (CPMI-MC, 2018). Moreover, some authors have speculated that CBDC's may be used to overcome the zero lower bound (ZLB) on monetary policy (in conjunction with the phasing out of physical cash) via negative interest remuneration (Bordo & Levin, 2017). Indeed, the discussion on CBDC's has mostly taken place during an era of low interest rates close to the ZLB, contrasting with the current interest rate environment.

Interest payments also raise concerns, such as how to calculate interest (e.g. what time span should be considered), or how to account for taxation (Engert & Fung, 2017), the latter complicating anonymous CBDC schemes.

Discussions on using interest rates to manage the demand for CBDC also hinge on crisis scenarios where, as it will be discussed in chapters 3 and 4, excessive demand for CBDC significantly reduces deposit funding for banks or opens doors to bank runs. Bindseil (2019) proposes a tiered interest rate mechanism to regulate the demand for CBDC, where small holdings are paid the prevailing, relatively more attractive interest rate but after a certain amount (e.g. the average monthly income of the country), it would earn a significantly lower interest rate, even a negative rate, if necessary. Significantly, this would allow the imposition of even extremely negative interest rates (provided bank notes were eliminated) while avoiding political backlash, since a certain amount of essential funds would not be covered by this rate, and the central bank could communicate the potential for this early on.

Alternatively, in a similar vein to monetary policy, central banks may choose between an "interest rate rule" or a "quantity rule" (Kumhof & Noone, 2021), that is, the central bank could choose to impose outright limits on how much CBDC an individual or firm can hold, directly controlling quantities rather than relying on market incentives. These limits could apply to the total amount held in balance or to (daily) transaction limits. Ahnert et al. (2024) present four drawbacks of limits in CBDC: (1) assuming firms have different liquidity needs than the public, different holding limits for different stakeholders may be necessary and may be difficult to calculate; (2) the singleness of central bank money may be broken[19]; (3) it may restrict the ability to receive a payment if said payment results in an account balance over the

[19] The denial of convertibility (beyond a certain limit) between deposits and CBDC possibly means the inability of arbitrage to equalize the value of all types of money (buying low, selling high until prices converge), potentially creating exchange rates between different types of money in underground exchanges.

limit[20]; (4) it may hamper the credibility of central banks if they end up not honouring the limit due to pressure. That said, limits are a potential tool to protect banks from deposit outflows (disintermediation), and from runs, and may be useful in a transition context, for example, temporarily imposing limits to allow the financial system to adjust to the introduction of CBDC (Group of Central Banks, 2021). Meller and Soons (2023) use a euro area calibrated simulation to show that a €3,000 limit would suffice to mitigate the impact on commercial banks' balance sheet.

Finally, note that CBDC characteristics from previous sections are not incompatible with each other, for example, a token-based CBDC could be arranged with a direct or indirect approach and with or without remuneration or holding limits, and so forth with many possible combinations (Auer & Böhme, 2020).

Now that the possible designs of CBDC have been presented, we will move on to the next part of the dissertation analysing its effects on the banking system, before advancing to other impacts on the financial system. Because we will be looking at the impact on banks stemming from the loss of deposits, the discussion will naturally focus on retail CBDC, since this is a CBDC that can be used by the public and thus can replace deposits.

[20] Although a reverse waterfall mechanism, where any funds received beyond a limit are transferred to a linked bank account (ECB, 2023) would overcome this problem, it would likely sacrifice anonymity since the CBDC account would need to be tied to a bank account with an identity.

3. CBDC and bank disintermediation

Banks use short-term liabilities (including deposits) to finance longer-term, illiquid loans, creating liquidity necessary to fund business projects which are illiquid, but yield returns over time (Diamond & Dybvig, 1983). To protect themselves against credit risk, banks perform monitoring of borrowers, in which they obtain specialization and thus lower the costs of monitoring (Diamond, 1984), in contrast with an economy with direct lending. Banking can promote economic growth: as banks can predict withdrawals based on the law of large numbers, they economize on holdings of liquid assets in an economy, and by providing deposits, they eliminate the need for individuals to accumulate excess liquidity to protect themselves against liquidity shocks. This reallocates savings from unproductive but liquid assets into capital investment and thus boosting economic growth (Bencivenga & Smith, 1991).

It has been posited that if a CBDC were to cause a flow of deposits away from the banking system, banks' benefits to the economy would be curtailed as they would struggle to fund business projects, with potentially negative consequences for investment and economic growth. Thus, CBDC's prospect of disintermediation of banks is a critical aspect in understanding its financial system implications. In this chapter, we will analyse the (static) balance sheet impacts of a CBDC issuance, how the banking sector and business model may shift due to CBDC, and the possible role of central banks in the new status quo.

3.1 Balance sheet effects

To analyse the potential impacts of a CBDC rollout on banks, a static, sectoral balance sheet analysis[21] will be employed to demonstrate two scenarios that are useful to break down the effects of CBDC on the banking system: the substitution of physical cash

[21] Papers that analyse the effects of CBDC on aggregate balance sheets include Bindseil (2019), CPMI-MC (2018), Group of Central Banks (2021), Kumhof and Noone (2021), Malloy et al. (2022) and Meaning et al. (2018).

for CBDC (scenario A) and a partial substitution of deposits at commercial banks for CBDC (scenario B).

For simplicity, in the first scenario, we assume that CBDC completely replaces physical cash, whereas in the second one the public only partially replaces their bank deposits for CBDC. We also assume that the central bank does not intervene with liquidity injections after CBDC issuance, so that the central bank's balance sheet does not increase, in contrast to Kumhof and Noone (2021), nor that CBDC is issued against securities (e.g. government debt). Thus, we assume deposit outflows to CBDC are settled with commensurate decreases in commercial banks' reserves (Abad et al., 2025; Malloy et al., 2022), which we assume banks hold in excess of the required levels, in line with the present circumstances (Abad et al., 2025).

The balance sheet structure, explained below, is inspired by Meaning et al. (2018), with the inclusion of wholesale funding similarly to Bindseil (2019) and Kumhof and Noone (2021). There are only 3 sectors: commercial banks, the central bank, and the household and non-bank firm sector. When it comes to balance sheet components, the central bank's is (initially) composed of securities, on the asset side, and reserves and banknotes on the liability side. Households and non-bank businesses hold deposits, securities, banknotes and wholesale funding as assets, and loans as liabilities (the remainder being their equity). Finally, commercial banks hold the loans that were extended to households and firms, as well as reserves, as assets, and fund themselves through deposits, wholesale funding, and equity. We abstract from certain monetary policy-related holdings such as central bank credit to commercial banks, as it does not affect the analysis.

3.1.1 Scenario A: CBDC substitutes physical cash

The first scenario is one where households prefer to substitute their banknotes for CBDC and keep their current level of deposits, for example, because the CBDC was designed to be more cash-like such as being token-based and offering anonymity (see Figure 2).

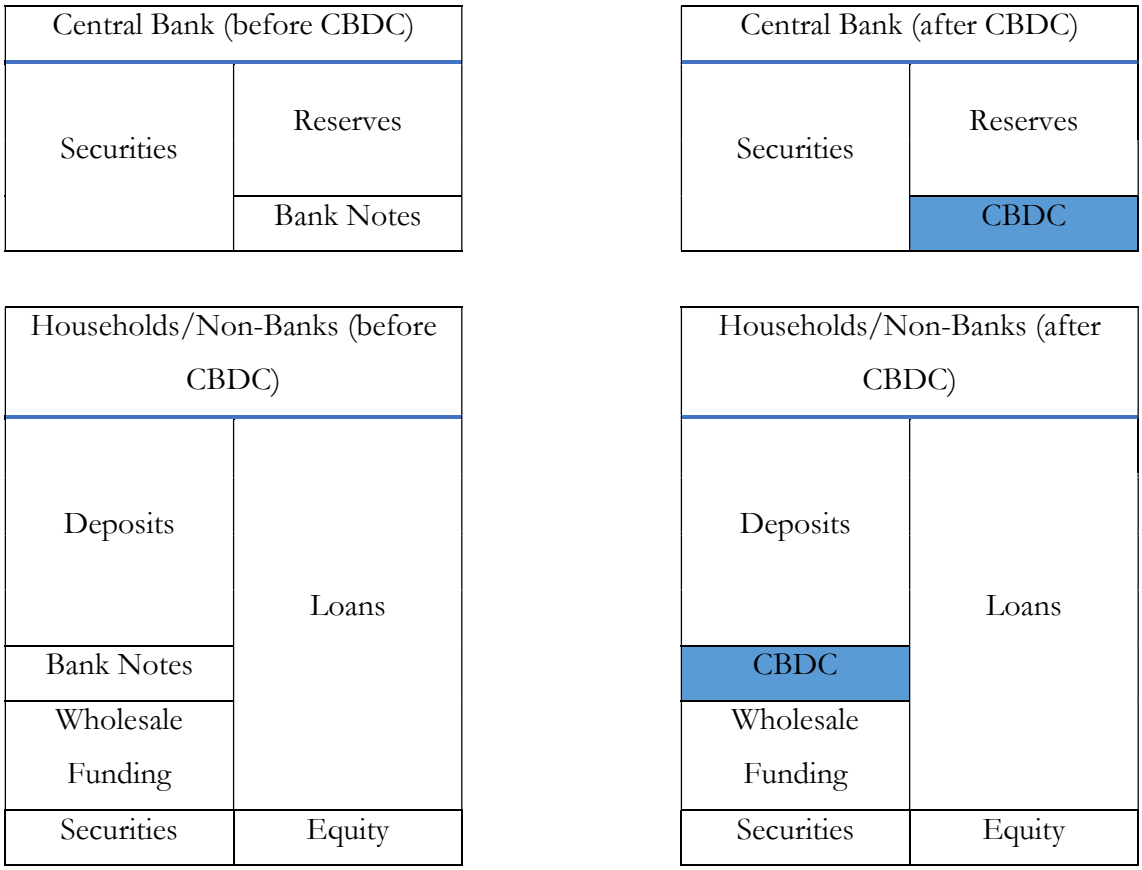

Figure 2 - *Balance sheet effects of CBDC replacement of banknotes.*

The result is that there is a substitution of liabilities in the central bank's balance sheet, from banknotes to CBDC and a parallel substitution of assets on the household and non-bank side (Group of Central Banks, 2021; Malloy et al., 2022). Crucially, the commercial banks' balance sheet is not affected since households do not exchange their deposits for CBDC, and thus that balance sheet was omitted in this scenario. This result would leave commercial banks' funding unaltered, avoiding disintermediation and thus should not have significant financial system implications.

Realistically, households would likely replace some of their deposit holdings for CBDC, especially if the CBDC design features mimics those of bank deposits, such as if it is account-based or if it is interest bearing. This contingency, scenario B, is covered in the next section.

3.1.2 Scenario B: CBDC replaces deposits at commercial banks

In this scenario, households prefer to hold some of their funds as CBDC instead of deposits, and thus exchange their bank deposits for CBDC, whether directly via the central bank or via an authorized intermediary (direct and indirect CBDC, respectively). As banks lose deposits, they lose a similar amount of reserves, and in this case, since the outflow is limited, they have enough excess reserves to cushion the blow, although their balance sheet size diminishes (Group of Central Banks, 2021; Malloy et al., 2022), as seen in Figure 3. In the central bank's case, there is a decrease in reserves and CBDC surges as a new component in the liability side, but since we assume there is no additional intervention, its balance sheet remains the same size, that is, the increase in CBDC is offset by a decrease in reserves.

In this case, the outflow is limited in volume so that bank's excess reserves are enough to contain it, saving banks from having to liquidate other assets or even loans, as well maintaining the central bank's balance sheet size. However, a large enough inflow of deposits to CBDC may require the central bank to inject reserves, which would necessitate an increase in its balance sheet.

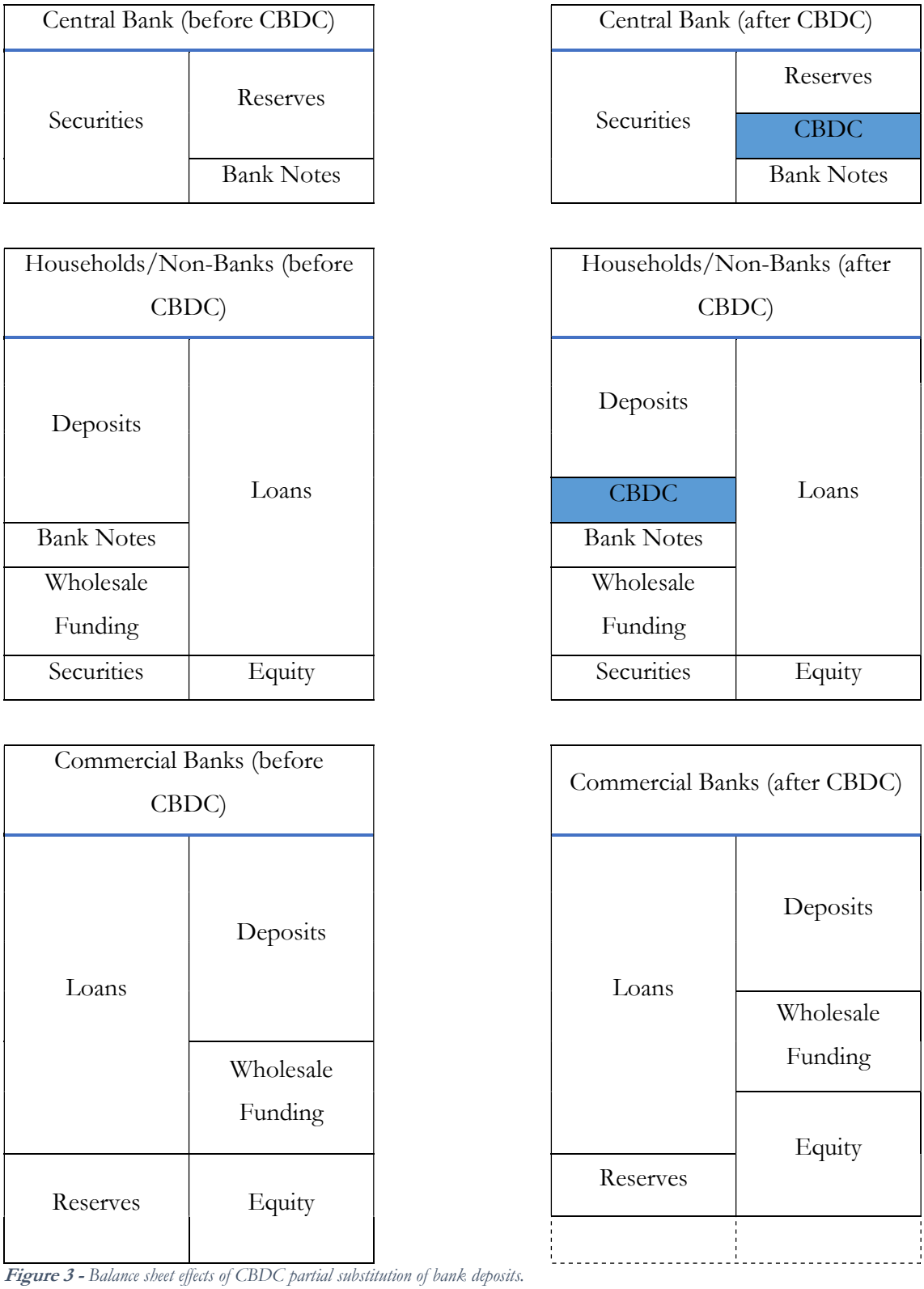

Figure 3 - *Balance sheet effects of CBDC partial substitution of bank deposits.*

We can also conclude that if deposit outflows to CBDC are small enough, bank disintermediation is mitigated. This could be due to a lack of demand for CBDC or through

limits on CBDC holdings, which can be used as an instrument to manage the financial stability consequences of CBDC (Meaning et al., 2018).

This balance sheet analysis provides an initial glimpse into how CBDC would impact commercial banks and the economy. However, banks are not passive actors and can respond to these developments, such as increasing interest rates on deposits to increase their attractiveness relative to CBDC[22] (Meaning et al., 2018). This and other consequences for banking are covered in the next section.

3.2 Bank responses, sector, and business model after CBDC

Faced with competition for funding, how will the banking sector be affected and how will it respond? First, it is clear that banks which are more dependent on deposit funding will be relatively more affected by a CBDC issuance (Mancini-Griffoli et al., 2018). As banks lose deposits, they also lose valuable information required for accurate credit screening and monitoring, potentially increasing credit risk and reducing lending (Bouis et al., 2024). Deposits themselves might become more volatile if a cheap and presumably safe alternative emerges. However, banks can respond in various ways and do not simply have to accept a potentially reduced balance sheet. In this section, we will look at how bank financial intermediation will be affected by CBDC in a more detailed way, covering impacts such as on the market structure of banking, credit supply, wholesale funding, bank risk-taking, and impact on non-interest income.

One option for banks to retain their deposits is to increase interest rates on them. As mentioned in section 2.3.4, as a competitor to banks deposits, an argument is made that a CBDC would increase the elasticity of deposit demand as depositors could easily shift funds to CBDC if it earned a higher, more attractive interest rate, compelling banks to increase interest rates to avoid losing deposits, essentially creating an interest floor on bank deposits (Mancini-Griffoli et al., 2018; Meaning et al., 2018; Niepelt, 2020). By making deposits more attractive, i.e., raising their interest rates, banks could contain or eliminate outflows to CBDC,

[22] Li (2023) predicts possible demand for CBDC using Canadian household data and concludes remuneration would be one of the principal factors determining its demand, and that banks can contain this demand by better remunerating deposits.

avoiding disintermediation. Banks would suffer from higher costs from this however, impacting net interest margin, and thus their profitability, unless they simultaneously raise interest rates on their loans, to the detriment of loan demand with a lower quantity of credit in the economy (Mancini-Griffoli et al., 2018). This reasoning however, is nuanced.

The extent of these impacts is likely contingent on the market structure of the banking system, that is, its degree of concentration. Andolfatto (2021) and Chiu et al. (2023) present uncompetitive banking models (monopoly and oligopoly, respectively) where banks constrain deposit supply and offer low interest rates on them, and in which an interest-bearing CBDC would force banks to increase interest rates on deposits to avoid losing them to CBDC. This attracts even more deposits and results in an increase in credit in the economy. This implies that a CBDC could even increase, instead of decreasing financial intermediation, if deposit markets are concentrated (Andolfatto, 2021; Chiu et al., 2023). In contrast, in a perfectly competitive market as presented by Keister and Sanches (2023), the issuance of interest-bearing CBDC results in a higher interest rate in deposits and loans, since it increases bank funding costs and thus limits the amount of projects they can finance.

The impact of a CBDC on deposits and loans is thus dependent on bank concentration: monopoly or oligopolistic banks have space to accommodate (forced) higher interest rates on deposits to a certain extent, increasing total deposits and credit in the economy relative to a world without CBDC, but after a certain limit, higher CBDC rates will lead to both decreased levels of deposits and credit as banks cannot sacrifice any more margin (since their profits would be negative), with banks eventually increasing interest rates on their loans to maintain profits (Chiu et al., 2023). In contrast, in a perfectly competitive market, the existence of zero profits implies that any increase in bank costs must be immediately passed on to customers (via higher loan rates) without any positive impact, and thus in this case a CBDC would have only negative consequences for the supply of credit (Bouis et al., 2024; Keister & Sanches, 2023). Additionally, in Andolfatto (2021), increased interest rates increase deposit levels not just because it attracts funds from the unbanked population (increasing financial inclusion), but also by incentivizing saving from already banked individuals. In any case, we can conclude that it is likely that bank profitability will decrease, and that the higher the remuneration of a CBDC, the greater the costs for banks.

However, there are caveats to this argument. The demand for bank deposits is not solely dependent on their interest rates, as banks offer a variety of services that make deposits

attractive which may not exist in a CBDC, such as credit lines, online banking, personal and mortgage loans, among other services (CPMI-MC, 2018). Experience shows that retail deposits are stable sources of funding, as withdrawals are easy to predict and costs of switching are high (Huang & Ratnovski, 2011; Mancini-Griffoli et al., 2018), although these costs may decrease if CBDC is designed to be low cost and easy to use (Group of Central Banks, 2021). All in all, it is not clear that a remunerated CBDC would place such tremendous pressure on banks and significantly push up deposit rates, even if it would increase competitive pressure. In other words, banks may not have to raise interest rates on deposit by much to maintain their deposit funding.

Furthermore, banks may try to replace deposit outflows with wholesale funding. Bank liabilities can include deposits and wholesale funding, the latter including more short-term, money market securities such as certificates of deposits and repurchase agreements or longer-term funding such as covered or uncovered bonds (Truno et al., 2017). To comprehend the impact of CBDC on banks, it is necessary to understand the differences between deposit and wholesale funding, as well as bank wholesale funding in general, since banks may use it to replace CBDC-induced deposit outflows.

Firstly, deposit funding is cheaper compared to wholesale funding due to both explicit and implicit government guarantees, and thus depositors do not demand as a high a risk premium for extending funds to commercial banks, leading to cheaper funding costs (Mancini-Griffoli et al., 2018; Ueda & Di Mauro, 2013). If these deposits are switched for CBDC, banks could lose this advantage and be forced to pass higher funding costs onto loan rates, at the cost of credit in the economy.

Wholesale funding is also less stable (Mancini-Griffoli et al., 2018) and "flighty" (Malloy et al., 2022, p. 12), compared to sticky deposit funding. On the one hand, wholesale financiers have incentives to monitor bank risk taking, requiring higher interest rates or pull out funds if banks behave irresponsibly (Calomiris & Kahn, 1991), in theory leading to more financial stability and stable funding, in contrast to secured deposits. On the other hand, there was evidence to the contrary in the run up to the 2008 global financial crisis as banks who were more dependent on wholesale funding proved to be more fragile (Demirgüç-Kunt & Huizinga, 2010). For instance, creditors did not have adequate incentives to appropriately monitor banks, as they could always not roll-over loans provided to banks and recover their funds in a short amount of time, and thus skip expensive monitoring (Oura et al., 2013).

More generally, noisy signals on the quality of the bank's balance sheet could lead to funding crunches in wholesale markets (Huang & Ratnovski, 2011), which can contribute to its unstable nature. This instability of funding suggests that a CBDC could cause bank credit to become more procyclical (Group of Central Banks, 2021) and cause volatility in loan rates because of banks' increased reliance on wholesale sources.

Another impact of increased wholesale funding of banks includes increased asset encumbrance[23] of commercial banks (Auer et al., 2024), as this sort funding typically requires collateral. In addition, increased wholesale funding demand by the banking sector as a whole after a CBDC issuance might increase its cost further, increasing pressure on profits (Group of Central Banks, 2021).

The concentration of the banking system may also be affected due to increased wholesale funding, as bigger banks have easier access to wholesale markets and can therefore protect their balance sheet more effectively than smaller banks (Whited et al., 2022). Thus, second-order effects related to structure of the banking system further complicate the analysis of the impact of CBDC on banking, as it could become more concentrated (Auer et al., 2022), not least to restore profitability deteriorated by CBDC competition: indeed, in Chiu et al. (2023), one of the effects of CBDC competition with deposits is a lower number of banks. Garratt and Zhu (2021) also conclude that the banking sector may become more concentrated, since big banks would be better equipped to deal with a CBDC due to their deposits' greater convenience (more ATM's and branches).

Moreover, as small firms tend to be disproportionately financed by small banks, it implies that the economic consequences of a CBDC-induced credit crunch would be heterogenous across firm size (Berger et al., 2017; Infante et al., 2024). In other words, if small banks are disproportionately affected by a CBDC, then so will credit to their clients, of which small businesses are excessively dependent on. In addition, as loan rates increase to retain profits, banks may attempt to pass these higher rates onto smaller businesses since these have lower price elasticity (Engert & Fung, 2017).

Another consequence of a CBDC would be that as banks are pressured to maintain profitability, they may resort to higher risk-taking, such as funding riskier, higher-return

[23] Asset encumbrance refers to assets that are not immediately available to banks due to being collateral in arrangements such as wholesale funding or other types of secured funding (Berthonnaud et al., 2021).

loans. CBDC may be thought of as new competition for commercial banks, and increases in competition in the past have been shown to increase bank risk-taking in attempts to restore profitability, such as the repeal of anti-competition laws (Ahnert et al., 2024; Keeley, 1990). Increased costs in general may likewise create incentives for banks to alter their risk appetite.

However, there are forces that could push banks in either direction. One line of argument is that the threat of deposit outflows to CBDC would increase discipline in banks, taking less risk and holding more liquid assets to avoid losing deposits (Berentsen & Schär, 2018; Engert & Fung, 2017). Another argument is related to deposit insurance, and the related moral hazard, as banks are able to take on more risks because of insurance schemes since bank creditors lose incentives to discipline them, since they could be always bailed out[24] (Calomiris & Jaremski, 2016; Ioannidou & Penas, 2010). If insured deposits flee to CBDC, then the effect of moral hazard that comes with deposit insurance guarantees could decrease, creating more discipline, and thus result in less risk-taking by banks (though less risk-taking would hamper efforts at restoring profitability), and vice-versa if it is uninsured deposits that flee to CBDC (Mancini-Griffoli et al., 2018). Less bank risk-taking would therefore require that deposit outflows come primarily from insured deposits, and it is not clear that demand for a CBDC would be greater for holders of insured deposits, especially since these are in principle already safe precisely due to deposit insurance (CPMI-MC, 2018). The impact of a CBDC on bank risk taking is thus subject to many different opposing forces.

Whether from higher rates on deposits or from costlier and less stable wholesale funding, it is difficult to see how bank profits will not be under pressure following a CBDC issuance. As banks accumulate capital primarily via retained earnings (Cohen, 2013), it is also likely that bank capital will also be under pressure following a CBDC issuance (Whited et al., 2022).

Thus far we have discussed how bank's main activities will be affected, that is, deposit-taking and lending. But a CBDC would not just affect income from bank's main lending activities, i.e. interest income, it would also affect non-interest income. Bank fees related to payment services would likely be affected (CPMI-MC, 2018), especially if CBDC is designed for cross-border transactions, affecting not just banks but also fintech firms that

[24] Note however that increased prudential regulation can mitigate this risk (Anginer et al., 2014), though it does not eliminate it.

specialize in payments. In contrast, if a CBDC leads to a decrease in the use of cash (scenario A), then costs due to handling of physical cash would decrease (Group of Central Banks, 2021), diminishing pressure on profits.

Finally, if demand for CBDC is great enough so that banks lack enough reserves, adequate wholesale funding or fail to capture deposits back from CBDC, the final, more extreme option that is a common fear of CBDC would be the sell off of assets and the reduction of banks' balance sheets, reducing credit to the economy. However, securitization could be a possibility for banks: even if their balance sheet is reduced, banks can continue to originate loans as before and convert them into tradable securities and sell them investors, leading to an "originate-to-distribute business model" (Niepelt, 2020, p. 230).

3.3 Central bank's role

The central bank can take a more active role in the financial system in a post-CBDC world. For example, another solution to the outflow of deposits could be to replace it with central bank funding, or as Brunnermeier and Niepelt (2019, p. 28) put it, "render the central bank's implicit lender-of-last-resort guarantee explicit", avoiding a shrinking of the aggregate balance sheet of banks and the selling of assets. This option can be also be used as a temporary solution as CBDC is introduced so that banks can better manage liquidity in an early CBDC environment (Group of Central Banks, 2021). But should this provision become a long-term solution for a CBDC-induced deposit outflow from banks, what would be the consequences for financial intermediation, and more generally, what roles and choices could central banks take up in a CBDC scheme?

This option requires an expanded role of the central bank in the banking system, as the balance sheet of the central bank must expand to accommodate bank funding (Kumhof & Noone, 2021). Central Banks would likely require adequate and safe collateral, at least in an early stage, before moving on to riskier assets (such as loans), such that asset encumbrance would also increase for banks, similarly to wholesale funding.

Niepelt (2020) suggests a scenario of how financial intermediation could take shape with a substitution of deposit funding for central bank loans: commercial banks could

maintain their functions of monitoring and screening of businesses in need of financing, but funding for loans would either have to come directly from the central bank, or they could be sold to the central bank, giving rise to the aforementioned "originate-to-distribute" model[25]. However, the author points out this may create perverse incentives where commercial banks would no longer appropriately screen projects, as they would always be able to finance or sell loans to the central bank, resulting in inefficient, possibly risky projects being financed, negatively affecting the economic growth.

Another way the central bank can intervene to safeguard the role of banks in financial intermediation is by opting for the "indirect" CBDC scheme where banks manage their customer's CBDC account (though the funds would remain at the central bank), which would allow banks to maintain the relationships with clients which are so crucial for monitoring and screening borrowers (Bouis et al., 2024).

A more transformative scenario would involve the central bank directly participating in financial intermediation, even if it did not completely take over the role of commercial banks (in contrast, Niepelt (2020) discusses a scenario where central banks do not directly interfere in maturity transformation). Firstly, it is not clear that a central bank would provide the same efficiency in credit allocation compared to the private sector, and moreover, there would be infrastructural roadblocks: as central banks do not currently have the resources and personnel necessary to participate in credit extension, massive investments would need to be undertaken (CPMI-MC, 2018). As central banks become more active in financial intermediation, credit extension may be subject to political pressures. For example, the central bank could give priority to well-connected individuals and firms which would distort capital allocation (Ahnert et al., 2024). Investments may be subject to certain pressures, "for instance, to require the [central] bank's investment policy to meet certain "ethical," "social," "ecological," or other standards" (Niepelt, 2020, p. 226). Other problems may also arise, even if central banks do not participate directly in financial intermediation. For example, they might be exposed to pressures from certain parties to increase or decrease the interest rate on CBDC (Ahnert et al., 2024), potentially threatening its independence.

[25] Note that this model can be implemented either by selling loans to private investors, as discussed in the previous section, or to the central bank, both approaches mentioned in Niepelt (2020).

Alternatively, an increased role of the central bank may also bring positive results. As the central bank enjoys independence, its greater involvement in financial intermediation could resist aforementioned pressures and fund investments in projects that are socially valuable (Ahnert et al., 2024). Another argument is related to the moral hazard of deposit guarantees, whose impacts could be mitigated if the central bank took on more responsibility for capital allocation (Dyson & Hodgson, 2016), decreasing the importance of large banks.

Another question concerns the collateralization of this new central bank funding to banks. Collateral can be of use to the central bank beyond protection from credit risk. The proposal of Kumhof and Noone (2021) to control CBDC demand hinges on the use of collateral: banning direct convertibility between CBDC and deposits at commercial banks and issuing CBDC only against eligible collateral. This is meant to safeguard funding for banks after a CBDC is introduced: for example, if an individual or firm were to attempt to obtain CBDC, whether through a bank or an authorized private intermediary, they would have to first obtain the eligible collateral, e.g. government securities, in order to trade them for CBDC. As the individual or intermediary in question first had to transfer deposit funds to the supplier of the security in order to acquire it, deposits remain within the overall financial system, they merely shift to the person who ultimately supplied the eligible collateral, and significantly, "the counterpart of increases in CBDC holdings is decreases in private sector government bond holdings, not in deposits" (Kumhof & Noone, 2021, p. 562), and thus banks' balance sheets would remain the same size, provided the source of bonds did not come from the banks. Furthermore, even they did, and banks' balance sheets were reduced due to decreased holdings of the eligible securities, credit (i.e. loan assets) to the economy would not be reduced, only the securities in question. Thus, the central bank could use collateral requirements in a CBDC scheme beyond simple balance sheet protection, it can also be used to help maintain bank funding and the supply of credit.

In addition, although the central bank's supervisory role already encompasses the monitoring of banks' lending activities, regulation in this context will likely have to be reviewed and tightened (Niepelt, 2020), especially in a scenario of extremely large take up of CBDC, where the central bank may have to fund increasingly riskier bank assets or accept them as collateral, in order to ensure investments do not impact the stability of the financial system. Moreover, due to possible changes in the composition of bank funding, such as decreased reserves and increased wholesale funding, regulatory standards (e.g. Net Stable

Funding Ratio in Basel III) will be impacted (Auer et al., 2024; Bouis et al., 2024; Group of Central Banks, 2021), and may need to be reassessed for a new post-CBDC world.

As we have discussed the impact of CBDC on banks' financial intermediation, we have abstracted from considerations related to bank runs, which can have very negative consequences for the financial system. In the next chapter we will analyse how CBDC's affect the risk of bank runs, and how this could impact banks and the financial system.

4. CBDC and bank runs

The possibility of bank runs with the use of CBDC has been a persistent worry for policymakers. Bank runs occur when large amounts of depositors seek to withdraw their deposits out of a bank in the belief that it will fail, whether by transferring deposits to another bank, or by converting them into physical cash (Mishkin & Eakins, 2024). Banks are subject to runs because of the maturity mismatch in their balance sheet: banks fund long-term illiquid loans with (largely) short term funds, namely deposits (Diamond & Dybvig, 1983). If banks do not have the liquidity to pay them out on demand, they may be forced to engage in asset sell-offs significantly below their value, potentially leading to insolvency (Diamond & Dybvig, 1983). Banks may finance inefficient investments, which leave them with bad, non-performing loans and thus also becoming insolvent, unable to meet their liabilities (including deposits), and news about the health of bank assets can rapidly spread, causing depositors to attempt to salvage their deposits before others (Mishkin & Eakins, 2024). Even depositors which are not worried about their bank's health have incentives to withdraw during a run, in fear that their deposit will not be paid in anticipation of others demanding withdrawals, which can give rise to self-fulfilling prophecies (Diamond & Dybvig, 1983). Bank runs have negative economic consequences as credit extension and the benefits of financial intermediation are reduced, potentially causing financial crises, with investment and consumption decreasing (Diamond & Dybvig, 1983; Mishkin & Eakins, 2024).

The problems associated with bank runs have over time given rise to various regulatory frameworks, lender of last resort (LOLR) facilities and deposit insurance to mitigate incentives to run and help manage its consequences (Broadbent, 2016). Because CBDC would be a safe asset, due to it being a liability of the central bank, and it would be attractive to switch to in case of a loss of confidence in banks, which reignites fears about bank runs. Using the framework of Bindseil (2019), we can identify 3 types of bank runs: from bank deposits to cash, from bank deposits to other bank deposits (i.e. from one bank to another), and with a CBDC, from bank deposits to CBDC. While it is unlikely that CBDC increases the run risk of the first two types, we can recognize the rise of a new type of run: bank deposits to CBDC. These "digital" bank runs would be more disruptive than previous ones, since digital bank accounts, pervasive due to the digitalization of payment systems and

money, allow for the instantaneous transfer of funds at a click of a button. Even if banks would be able to accommodate flows of CBDC in normal times, in an event of a crisis scenario such as a bank run this probably would not be the case (Kumhof & Noone, 2021).

While digital runs are already technically feasible in runs from one bank to another, the presence of CBDC would allow an aggregate run from bank deposits (i.e. from all banks) to CBDC (Mersch, 2017). The possibility of an aggregate run out of the banking system to the central bank would present tremendous challenges to financial stability, as the entire banking system would see their activities disrupted, rather than just one bank.

There is, however, also reason to believe that CBDC's would not necessarily affect financial stability, and in some cases may even help increase it. Thus, in this chapter we look over arguments and factors that may, on the one hand, increase the risk of bank runs or, on the other hand, decrease the risk of bank runs after CBDC is introduced.

4.1 Factors that increase run risk

A common reasoning that CBDC would amplify bank run risk is that by being a liability of the central bank and thus issued by it, the central bank can always create liquidity to satisfy depositor's demands. This might cause the public to choose to trade their bank deposits for CBDC in a situation where there is a loss of confidence in the banking system. Indeed, in the model of Fernández-Villaverde et al. (2021) of the Diamond and Dybvig (1983) tradition, this causes a complete shift of deposits to CBDC, as depositors know this ex-ante and shift their deposits to the central bank, illustrating the risks of aggregate runs out of the banking system.

Different types of runs also have different costs to depositors. Flights to cash are more costly than digital ones since depositors have to physically go to a bank branch, withdraw cash (perhaps multiple times over a week due to daily limits or fees) and find an appropriate and safe space to storage it to avoid theft (Niepelt, 2020). A CBDC, in contrast, would allow an instantaneous transfer of deposits to a safe location without costs[26]. While

[26] The central bank would presumably design a CBDC to be low cost, convenient, instant and available, according to the design features and principles set out by Group of Central Banks (2020).

counter-arguments state that near-instantaneous digital runs are already feasible in interbank runs, as depositors can simply digitally transfer deposits out of their accounts to other commercial banks, a crucial difference lies in the fact that a CBDC, due to its risk-free nature, would provide a quick and recognizable avenue to switch to, whereas in a world without CBDC, depositors must first determine which banks are safe enough to transfer their deposits, i.e. it entails switching costs (Kumhof & Noone, 2021). A CBDC would essentially eliminate costs of searching since the public would be aware of the existence of this safe asset before and amidst a panic, and quickly their trade deposits for it without the time or need of searching for a safe haven. In addition, this low cost of switching could aggravate runs even in minor crises where rumours about a bank's health are not particularly negative, but depositors nonetheless transfer their deposits to CBDC as a precautionary measure (Dyson & Hodgson, 2016), as it would not cost anything to switch between accounts. Additionally, by making the act of running easier, it could increase the risk of runs because one motivation behind runs is the observation of others doing it as well: if a CBDC makes runs easier and makes more depositors withdraw, then others will run as well (CPMI-MC, 2018).

Increased risks of runs may also arise as second-order effects of disintermediation: Kim and Kwon (2023) conclude that as a CBDC diminishes bank credit to the economy and drains reserves from banks, a CBDC increases the risk of bank runs as banks have less buffers to contain deposit outflows[27]. Other risks can arise from increased wholesale funding, since historically, wholesale creditors have abruptly removed funding (see section 3.2). This greater fragility in funding may also induce runs by retail depositors, as bank fundamentals and liquidity deteriorate, depositors can observe this and withdraw their own funding (deposits). Thus, increased wholesale funding could serve to increase the risk of runs not just to CBDC but even to other types of assets (e.g. deposits at other banks, cash). In addition, as small banks would have greater difficulty in replacing deposit funding, they may be at greater risk of runs as they would not easily manage liquidity crunches (Bouis et al., 2024).

Other arguments question the ability of certain design features of CBDC to safeguard financial stability, such as (unattractive) remuneration and quantitative limits, discussed in section 2.3.4. The rationale behind said design features is that, if there are appropriate safeguards, then CBDC need not jeopardize financial stability. Indeed, the ease of switching

[27] Though in their model, the central bank can, in another scenario, finance commercial banks, eliminating these negative effects.

to CBDC compared to other traditional liquid assets is a rationale for imposing limits or switching costs on a CBDC. However, in addition to the limitations and possible adverse effects of quantitative limits that were discussed previously (e.g. emergence of exchange rates between types of central bank money), there are fears that even extremely negative interest rates on CBDC will not be enough to dissuade runs out of the banking system, due to the state of panic characteristic of financial crises, and thus there may be no rate negative enough to satisfy stressed depositors (CPMI-MC, 2018; Group of Central Banks, 2021; Kumhof & Noone, 2021). In addition, even if limits could prevent runs, they can only do so by significantly reducing the utility of CBDC, ultimately rendering it not as useful for transactions (Auer et al., 2022; Callesen, 2017), defeating its purpose. Limits, while imposed to contain runs, may even be counterproductive in the aggregate because the exchange rates between types of money that may arise could induce some to obtain additional amounts of CBDC before others, anticipating the limit will be reached (Mancini-Griffoli et al., 2018).

Finally, if banks start taking on more risk to restore profitability lost to CBDC competition, financial stability in general might decrease, including a higher risk of runs (CPMI-MC, 2018; Infante et al., 2024), since the risk that their financial position deteriorates would increase. However, as concluded in section 3.2, these effects seem ambiguous as there are forces that may push banks in either direction when it comes to risk-taking, so that the final impact on bank risk taking and its impact on bank runs, is unclear.

4.2 Factors that decrease run risk

The common argument in defence of CBDC is that depositors can already digitally flee a struggling bank by simply transferring their deposits to another bank that is in safe financial conditions, so that CBDC would simply be another asset to run to and thus would not really increase the risk of runs. In addition, depositors can also flee to state-owned or backed banks which, due to government influence, are already seen as safe as a CBDC (Mancini-Griffoli et al., 2018). When it comes to aggregate runs out of the banking system, it can be noted that depositors can also already flee to non-bank assets, such as government bonds, so that a CBDC would not increase the risk of aggregate bank runs because they can already occur in a world without it (Auer et al., 2022). Indeed, one line of argument is that

uninsured, higher-value deposits are likely to flow not to CBDC in a bank run scenario, but rather to (more attractive) government debt (Koning, 2018), especially if CBDC bore (relatively) little to no interest. Moreover, deposit insurance will continue to prevent bank runs (Mancini-Griffoli et al., 2018): in principle, if a deposit is covered by deposit insurance, there is no reason to run since the depositors can be reimbursed in case of a bank failure and are thus not in danger of losing their savings, which further casts doubt on the financial stability risks of CBDC.

Yet, runs out of the banking system in the aggregate, in other words, runs where deposit outflows are large enough so that banks do not have enough excess reserves to contain them or even extremely negative interest rates are not enough to dissuade outflows, remain a possibility and are a significant concern of a CBDC issuance. However, a crisis that generates flows to CBDC of that magnitude is likely to be an extreme event where the financial system has undergone a serious loss of confidence due to, for example, severe liquidity and bank solvency problems, and thus its causes are unlikely to be related to CBDC simply existing (Dyson & Hodgson, 2016) and would cause tremendous damage regardless of any CBDC, and therefore such reasoning does not provide a sound basis for rejecting the issuance of CBDC.

While the digital nature of these runs is often seen as destabilizing factor (namely due to the greater scale and velocity of runs), it can be reasoned that, on the contrary, the chaotic and viral scenes associated with classic flights to cash would not occur, such as big lines at branches and ATMs, as depositors would digitally transfer their deposits to CBDC and easily satisfy their request (Koning, 2018). If CBDC substitutes cash as the safe haven during runs, panic can be mitigated and with it the risk of runs.

One scenario after a CBDC is issued is that central banks provide liquidity to commercial banks to compensate any shortfall in deposit funding, and this has been posited to impact the risk of runs. In particular, the role of the central bank as the LOLR can function as a stabilizing force: as the central bank increasingly becomes a major source of bank funding, it can "internalize the run externalities" (Brunnermeier & Niepelt, 2019, p. 38) and simply not run as it can compensate any shortfall in deposit funding (Brunnermeier & Niepelt, 2019; Niepelt, 2020; Pfister, 2019). In other words, as central bank's increasingly fund commercial banks, their role as LOLR becomes explicit (as they directly fund banks), which reduces the risks of runs, including by altering depositors' motivations, as they would

have even less incentives to run, since the central bank would immediately make up decreases in deposit funding (Brunnermeier & Niepelt, 2019).

Another defence of the beneficial effects of CBDC in containing runs comes from Keister and Monnet (2022), which analyse the means through which a CBDC could increase financial stability. Because a CBDC would allow regulators to observe flows from banks to CBDC, the authors posit that this can allow them to identify which banks are in need of intervention sooner, resolving those banks faster and thus increasing financial stability. In a pre-CBDC world, regulators may have in difficulty in identifying outflows (to cash or to other banks) or distinguishing them from regular ones, which makes it longer to identify weak banks. This time lag in turn creates incentives for bank runs, as the higher the number of withdrawals, the greater the haircuts on the remaining deposits, since such withdrawals are a drain on bank resources. This is compounded by the fact that banks may hide information about the quality of their assets (or liquidity) to forestall regulatory intervention, even if only for a limited time. Post-CBDC, since regulators will have access to outflow data, they can mitigate these incentives by identifying weak banks sooner, and because depositors or bank creditors identify this ex-ante, this reduces their incentives to run and thus the probability of bank runs, increasing financial stability.

A related argument in the context of bank resolution comes from Kumhof and Noone (2021), who point out that CBDC can be used to quickly appease panicked depositors by paying them in CBDC. Without CBDC, the process of resolving banks may linger, which locks depositors out of their funds and thus incentivizes them to withdraw their deposits from banks, propagating instability across the banking system. Thus, a CBDC can reduce the risk of bank runs by mitigating the spread of panic in distressed banks, since the long process of bank resolution becomes irrelevant to depositors' actions as they can swiftly be paid in CBDC.

Finally, remuneration of CBDC can also be a factor in bank runs: in contrast to bank notes, a CBDC may be interest-bearing which increases incentives to run as it becomes a more attractive asset to hold. Ahnert et al. (2023) study how a remunerated CBDC could impact financial stability: in a global-games bank run model, a remunerated CBDC increases fragility (the probability of bank run) because it is a new asset to run to (the direct effect), however, the monopolist bank can respond by increasing interest rates on deposits, provided they have lucrative investment opportunities, decreasing the risk of bank runs (the indirect

effect). Within a range of CBDC rates, the indirect effect dominates the direct effect, increasing financial stability, that is, the relationship between CBDC remuneration and the risk of bank runs is U-shaped. However, if the remuneration of CBDC is high enough, the direct effect becomes dominant, and financial fragility increases, as the bank cannot raise the deposit rate without increasing its probability of becoming insolvent (due to the higher funding costs). These findings are consistent with Chiu et al. (2023) and Andolfatto (2021), in which the relationship between bank lending and CBDC remuneration is also non-monotonic. In an extension of their model, Ahnert et al. (2023) analyse how the probability of bank runs changes with perfect competition: an increase in the CBDC rate always increases financial fragility since banks cannot raise deposit rates without incurring in losses, a conclusion in line with Keister and Sanches (2023). These insights contribute to the evidence that in a concentrated banking sector, a CBDC may serve to increase welfare, running counter to common apprehensions.

Thus far we have looked at how banks may be impacted by a CBDC, which are a key component of the financial system. A CBDC would have diverse impacts on various sectors, agents and assets in the financial system however, not just banks. In the next chapter, we will discuss other financial system implications of CBDC.

5. Other financial system repercussions of CBDC

In chapters 3 and 4 we reviewed the impacts of CBDC on the banking system. However, a CBDC would not just affect banks but also non-bank financial institutions (NBFI's), such as various institutional investors, investment funds, non-bank lenders, payment service providers (PSP), and may have various other impacts on the financial system in general. For example, dynamics in financial markets related to asset prices may be affected, and if a CBDC is designed so that it can be held abroad or by foreigners, numerous international disruptions may arise.

While banks are a major part of the financial system, in this chapter we will complete our analysis by looking at non-bank related consequences that may arise from CBDC, in order to get a more encompassing view of the potential financial system implications of CBDC. This chapter will be organized as follows: first, there will be a discussion on the possible role and impacts of increased non-bank lending that may result from CBDC issuance, followed by potential effects of CBDC on other NBFI's and in financial markets, and conclude with a review of the international implications of CBDC.

5.1 Increased non-bank lending

Due to the concerns of CBDC competition with bank deposits and thus its possible threat to bank funding, until now the focus has been on the banking sector side of the financial system, since banks have a vital role in the provision of credit to the economy, which could be affected with the issuance of CBDC. However, even if CBDC does significantly affect deposit funding for banks, non-bank lenders may potentially step in and fill the gaps provided "they chose to adjust their own portfolio composition" (Group of Central Banks, 2021, p. 11). Indeed, one option mentioned in section 3.2 was that banks can increase wholesale funding to deal with shortfalls with deposit funding, which can also entail funds from non-banks, however in that scenario banks would still maintain their functions of resource allocation and decide which projects get financing. How would the financial

system change if non-banks increased participation in credit extension? What would be its benefits and downsides?

Firstly, if greater interest rates on loans do in fact result from CBDC issuance as banks attempt to pass on higher deposit rates (see section 3.2), then this would allow greater competition from non-bank credit, which could even mitigate said interest rate increases (Group of Central Banks, 2021). As lending from non-banks becomes more prominent, the economy could stand to benefit from its advantages relative to bank funding. Claessens (2024) denotes that as this type of funding often takes the form of financial instruments (e.g. bonds, shares), we can deduce the benefits of non-bank lending by looking at the gains from capital market funding in the economy, which include: (1) the provision of investment opportunities with various long-term maturities while still providing high liquidity, i.e. redemption of funds on a daily basis, (2) specialization in specific industries and asset classes, and (3) its decentralized structure compared to banks, which leads to more efficient financing of projects. In addition, it can have financial stabilization benefits due to the risk-pooling these instruments may offer (which also benefits investors), and since many non-bank lenders are not part of the payments system, an individual bankruptcy can have less systemic effects. Moreover, a greater portion of credit coming from non-banks can provide diversification of credit sources (Ehrentraud et al., 2024), which may improve the services banks offer due to the pressure of greater competition. Additionally, non-bank lending can provide an additional source of credit in cases where the banking system is in crisis, or, provide a "spare tire" (Greenspan, 1999) to the economy. For example, empirical evidence from countries with greater capital market funding, albeit not necessarily from NBFI funding[28], have been shown to recover more quickly from financial crises (Claessens, 2017, 2024).

In addition, non-bank lending may increase financial inclusion in various ways, and in turn increase overall credit to the economy, promote investment and increase economic growth: many fintech firms provide credit to individuals and businesses that cannot access credit provided by banks (Cornelli et al., 2024). Moreover, if CBDC spurs greater financial inclusion by getting unbanked individuals to obtain a CBDC account (though this is more unlikely in advanced economies), lending can increase provided that the CBDC scheme in

[28] Commercial banks also participate in capital market funding, for example, when issuing bonds or through securitization of loans.

question consists of partnerships that include non-bank lenders (indirect CBDC). Not only would this increase the reach of potential clients for these lenders but also would allow non-banks to use digital transaction data from these accounts to screen and monitor borrowers (Bouis et al., 2024). Additionally, the increased role of fintech firms in the supply of credit can help spread innovative processes such as the use of Big Data and algorithms (see section 2.1) to process client data, which are used to screen and monitor borrowers (Claessens et al., 2018), increasing efficiency in credit extension, since it can ultimately be adopted by banks.

However, there can be negative effects as well. Similarly to banks, some NBFI's such as open-ended investment funds can also suffer from run-style events, where investors demand to redeem shares in funds following a lack of faith in the fund or declines in the value of its assets, hoping to retrieve their funds before other investors (Claessens, 2024). This is particularly relevant if those assets are relatively illiquid, which can lead to fire sales in attempts by the fund to raise liquidity to pay out investors, i.e. assets are sold below their fair value. In addition, credit supply may become more procyclical, since non-bank lending has been shown to contract sharply during crises, as is observed with wholesale funding of banks. For example, Aldasoro et al. (2023) find that during financial crises, global syndicated loans by non-banks contract 50% more than that of banks. Procyclicality is also related to a major difference between bank and non-bank lending, that is, relationship versus transactional lending, respectively. Non-banks tend to rely solely on hard financial data when assessing potential borrowers whereas banks rely not just on figures but also on personal long-term relationships and qualitative analysis. Aldasoro et al. (2023) find that this greater decline in lending of non-banks versus banks is significantly reduced if relationships are accounted for, both in their duration and intensity.

Moreover, it is not clear if these types of lenders, such as those associated with fintech firms, perform classic bank functions as efficiently, especially as commercial banks may have informational advantages from having access to information from deposits that non-banks may not have access to, especially in the context smaller firms (Group of Central Banks, 2021).

Finally, because many of these lenders do not have access to deposit insurance and are not subject to the same legal framework as banks (Gruenberg, 2023), which is made difficult by the lack of data (Ehrentraud et al., 2024), regulatory and supervisory frameworks would have to be revised in order to increase the prominence of this funding source as well

as to reduce their associated risks. This is especially true in the context of the euro area, as regulatory hurdles and lack of integration have made capital market financing lag behind other economies (de Guindos, 2023).

5.2 CBDC, NBFI's and asset prices

As CBDC issuance may increase the role of NBFI's in the financial system beyond non-bank lending, in this next section the focus will be on how this new type of money can affect these institutions. In addition, we will look over how indirect impacts of CBDC issuance may affect the dynamics in financial markets by analysing its effects on asset prices.

5.2.1 CBDC's and NBFI's

A CBDC can directly affect NBFI's, for example, because these institutions may also suffer from similar run dynamics into CBDC as banks. While in the previous section we explained how these institutions can suffer from runs into bank deposits or other traditional safe havens, a CBDC, by being an additional safe asset to run to, can also incentivize run-style dynamics out of these funds and into CBDC, not just runs out of banks (Group of Central Banks, 2021; Infante et al., 2024). Similarly to the discussions on bank runs, although this would already be possible today, CBDC may increase these incentives, since the presence of a safe and potentially remunerated central bank liability may provide greater incentives to investors, for example, to redeem their shares in funds into CBDC by comparison to a redemption of shares into bank deposits. For example, in the context of a financial crisis, mutual funds may experience increased outflows and stress, as a CBDC creates greater incentives for withdrawals by comparison to bank deposits. Of course, and similarly to discussions on the increased risk of bank runs, it is possible that CBDC will not increase these incentives, as other extremely safe and liquid assets to run to already exist, such as government bonds (Mancini-Griffoli et al., 2018).

Some financial institutions may be more affected by competition from CBDC than others, but not in the context of run-style dynamics. For example, as they invest in short-

term safe debt securities, money market mutual funds (MMF) may be particularly affected by CBDC's as some investors might favour holding their funds in CBDC rather than in said MMF's (Group of Central Banks, 2021), especially if CBDC is competitively remunerated. However, if these financial institutions were allowed to hold CBDC, this incentive may be mitigated, as funds themselves could hold CBDC in their portfolio.

CBDC could also impact the payment services sector, an important part of the financial system. An indirect CBDC model (see section 2.3.1) could provide an opportunity for more competition in payments systems, which tends to have a strong presence of banks. Because this scheme would involve the central bank entering into a partnership with the private sector (for example, intermediaries managing accounts on behalf of the central bank but not legally holding the funds), CBDC could provide an avenue for new entrants as partnerships could be extended to firms other than banks, such as fintech firms. Dyson and Hodgson (2016) point out that barriers to entry in the payments service system can be alleviated with CBDC[29], since in the current status quo entrants are reliant on infrastructure from large banks in order to enter the sector. Moreover, by providing an additional payment instrument, it may improve the resilience of the payments system, for example, in case infrastructure used by banks was placed under stress or if a bank experiences financial difficulties, as a CBDC would allow households to continue to make digital transactions (CPMI-MC, 2018). This could increase financial stability and mitigate the economic consequences of banking crises.

5.2.2 CBDC impact and competition with financial assets

A CBDC could affect asset prices in financial markets, since it could serve as a store of value (especially if it is interest bearing) and could thus compete with other safe and liquid assets.

As previously discussed, shifts to CBDC could cause changes in demand for the assets that various funds (e.g. MMF's) traditionally invest in, such as government short-term debt, which would affect not just those institutions but also the assets themselves. By virtue

[29] The authors use the term digital cash to refer to CBDC.

of being safe and liquid, a CBDC would in theory be in competition with other financial assets that fulfil these characteristics, not just with bank deposits. Similar pressures may arise if CBDC replaces short-term government debt in wholesale markets if it is made available to financial institutions and is used in settling wholesale payments (wholesale CBDC), potentially reducing the floating share of these assets (e.g. bonds) in financial markets, affecting not just the prices of these securities but ultimately market functioning with reduced depth post-CBDC[30] (CPMI-MC, 2018).

On the one hand, CBDC may directly compete with other liquid assets driving demand away from them, though, on the other hand, if CBDC is issued against eligible collateral, collateral scarcity may be an unintended consequence if inflows into CBDC were to be large enough, depending on how wide the list of eligible assets is. For example, Kumhof and Noone (2021) present estimates for the gilt market (as of 2016): with the total value of demand and time deposits being in the order of £1,950 billion and the market value of gilts being £1,430 billion, a situation where an extremely large outflow of deposits to CBDC occurs may force central banks to widen the range of admissible collateral, though the demand for CBDC would have to be very large, and expanding collateral eligibility would come with new risks. A similar but lesser pressure would form if CBDC resulted in increased wholesale funding of banks, as this funding would likely require the use of collateral.

Another impact on asset prices may come from the increased prominence of NBFI funding in the economy, which may cause greater volatility in asset prices. As discussed previously, NBFI's can suffer from similar run problems just like banks, both under current conditions and can potentially exacerbated with CBDC. For example, at the outset of the Covid-19 pandemic, mutual funds that invested in (illiquid) corporate bonds experienced significant stresses because as they attempted to sell their holdings of bonds, the prices of said bonds declined to due to fire sales which further contributed to the spread of illiquidity to other funds (Falato, Goldstein, et al., 2021). In other words, the fire-sale dynamics associated with certain investment funds created vicious cycles where declining assets values spilled-over to other funds that held the same assets, propagating liquidity problems and further fire sales (Falato, Hortacsu, et al., 2021). These mechanics may play a greater role in

[30] The reduced depth of these markets could also constrain the ability to create interest rate indices, as their robustness is built on the existence of numerous transactions (Group of Central Banks, 2021), with negative consequences due to the critical role said indices have for monetary policy transmission and more generally for the functioning of the financial system.

a world with CBDC and create volatility in asset markets if NBFI's become more prominent in the financial system.

Finally, CBDC has been posited as a means to lower the "near-money" premium on (safe) short-term liquid assets (CPMI-MC, 2018, p. 17). The rationale is that these low yields have incentivized the use of short-term liabilities to fund illiquid long-term assets, carrying negative financial stability risks (CPMI-MC, 2018; Infante et al., 2024). By providing the financial sector with large amounts of safe (i.e. central bank) assets, it would increase resilience in the financial system by disincentivising the use of callable short-term liabilities and promoting the use of safer central bank assets. This discussion predates CBDC, with large central bank balance sheets being seen as enhancing financial stability via this channel (Greenwood et al., 2016).

5.3 International implications of CBDC

Until now our discussion abstracted from any international implications of CBDC, whether that relates to a CBDC that is designed to be available to be acquired abroad, or other indirect consequences that a CBDC roll out may have internationally. A CBDC can be designed so that it can be accessed by foreigners, even if on a limited amount (for example, with transaction or balance limits). This could involve various scenarios, from tourists purchasing CBDC to use during their stay, its use to transfer remittances, to foreigners living abroad being able to obtain a CBDC account or wallet from a country different than their own. It may also involve partnerships between central banks where different CBDC's are made available to be exchanged in an easy and safe manner, whether through foreign banks, other PSP's or collaborative platforms created specifically for this purpose (CPMI et al., 2022). However, if CBDC's are designed to being exchanged and held across borders, several financial consequences may arise, which are discussed below.

First, monetary sovereignty may be threatened by foreign CBDC's if households and firms believe a that digital currency from another country is more stable, and use it in lieu of home currency, in other words, CBDC may spell currency substitution[31] (CPMI-MC, 2018).

[31] A similar concern exists regarding stablecoins.

This may be particularly problematic for countries with weak monetary fundamentals as a CBDC could accelerate the substitution of home currency for foreign ones (Bouis et al., 2024). It could also result in bank disintermediation as deposits flee the home banking system to foreign CBDC, increasing both the number and volatility of capital flows (Popescu, 2022), and bringing with it the negative effects of disintermediation of the banking system previously discussed, such as lower levels of lending and economic growth. Of course, issuers of highly credible CBDC would also be affected as they would receive capital inflows which, for example, may impact monetary policy implementation (CPMI et al., 2021).

This in turn can amplify banking crises and the risk of bank runs. For example, if a country goes through a decline in confidence in its banking system, depositors of said country may decide to transfer deposits to the CBDC of a safe country, creating flows from home bank deposits to foreign CBDC's (Dyson & Hodgson, 2016), which could create volatility in exchange rates. This would also worsen the currency depreciation of the country experiencing the crisis, in other words, CBDC's may exacerbate twin crises, where banking stresses are accompanied by steep currency depreciation (Laeven & Valencia, 2018). In addition, Minesso et al. (2022) argue, in a Dynamic Stochastic General Equilibrium (DSGE) model, that because a CBDC could offer both liquidity and remuneration, following a financial crisis, individuals would specifically prefer to switch to foreign CBDC by greater volumes than to foreign bonds (which offers remuneration but not liquidity services), leading to greater movements in the exchange rate compared to a world without CBDC, increasing international spillovers of crises. Moreover, in a scenario where banks hold primarily foreign assets (for example, as result of CBDC-induced currency substitution or in countries with poor monetary fundamentals), the LOLR function of the central bank may be threatened (CPMI et al., 2021), which would further endanger financial stability in countries impacted by outflows.

Thus, the discussions behind CBDC resulting in bank runs and disintermediation come with added force if it is used across borders, with banks seeing their competition for deposits increase to foreign CBDC. While developing economies tend to be more exposed to pressures of currency substitution, small open economies can still suffer from similar stresses, though issuers of reserve currencies are likely to be less affected (Popescu, 2022). Moreover, these threats will likely incentivize central banks to increase reserve currency holdings (IMF, 2020) to better counter depreciation pressures.

Popescu (2022) suggests ways in which affected countries can mitigate these effects, which are outlined below. When it comes to countries experiencing outflows, measures include conducting prudent monetary policy to increase the credibility of its central bank, the implementation (or strengthening) of credible deposit insurance to prevent bank runs, capital controls during crises times, and issuing their own CBDC to compete with foreign ones[32]. As for countries experiencing inflows, they would have to consider how such flows would impact monetary and financial stability in their own economies and design its CBDC in a way that optimally controls inflows[33]. In addition, cooperation between central banks is important to avoid further propagation of financial shocks, for example by offering swap lines to restore liquidity in the countries facing capital flight.

Moreover, CBDC's have been posited to upend and alter the international monetary system, with shifts in international currency reserves possibly emerging as a result[34]. While the United States dollar should retain its status for the foreseeable future due to its institutional credibility and reputation, the development of alternative cross-border CBDC infrastructure could create the scalability and liquidity that can allow new reserve currencies to emerge, reducing the costs of switching from currently dominant reserve currencies (IMF, 2020). For example, this new CBDC infrastructure could be used to conduct international trade and settlement of (foreign currency denominated) financial assets, promoting the use of other currencies. Alternatively, CBDC may make current reserve currencies such as the dollar even more preeminent by increasing its accessibility and decreasing the costs of acquiring it (CPMI et al., 2021).

That said, cross-border CBDC need not have solely negative repercussions. One of the primary drivers of issuing a cross-border CBDC is to increase the efficiency and removing frictions in transactions between different jurisdictions. Frictions include different communication standards, time zones, compliance requirements and unclear foreign exchange rates or fees, all of which increase costs as well as result in an excessive number of intermediaries (CPMI et al., 2021). In addition, a CBDC issued by a credible issuer can

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[32] Although if a currency suffers from lack of credibility and stability, issuing a CBDC would not change this (IMF, 2020).

[33] For example, the issuer can implement specific holding limits or interest rates for international CBDC accounts as a way to manage capital flows.

[34] This topic is extensive and beyond the scope of this dissertation.

increase the number of international safe assets, increasing stability during global crises and international sharing of risk during periods of global economic stress (Popescu, 2022). Ease of exchange between different CBDC's as a result of agreements between central banks may also improve access to international capital markets by decreasing transaction costs, exchange rate risk and reducing the reliance on banks (IMF, 2020), which can increase cross-border investment.

Of course, many of the negative impacts can ultimately be overcome with tools such as holding limits, though the benefits of cross-border CBDC outlined here would not be realized to the same extent. However, even if CBDC's are not available across borders, or if they are designed with enough restrictions that limit its international usage, a CBDC issuance can still indirectly impact the international financial system: if wholesale funding increases as a response to the dry up of deposit funding, banks may be able to obtain additional funding across borders in foreign financial markets. This could present additional financial stability risks, for example, if the funding was denominated in foreign currency: if funds are not rolled over, it may become very difficult to replace it, which will likely lead banks to hold more foreign currency assets and derivatives to better protect themselves against this risk (Bouis et al., 2024).

6. CBDC's in practice

While reviewing the potential impact of CBDC on the financial system throughout this dissertation, the discussion remained highly theoretical, without reference to real-world examples of CBDC and empirical data, which in the case of advanced economies, is non-existent since CBDC's have not been issued there. This chapter begins the second part of the dissertation, in which we will use case study analysis to analyse CBDC's, as well as its possible financial system implications, informed by the conclusions and insights derived from the research in the previous chapters.

We will analyse two case studies: the Bahamas' digital sand dollar and the eurozone's digital euro. On the one hand, studying the sand dollar will allow a glimpse into real-world impacts of a CBDC. On the other hand, the digital euro, despite not yet being issued, reveals how the central bank of an advanced economic zone is designing their CBDC, revealing insights into how the ECB is considering its impacts on the financial system.

In this chapter we will thus review the history, context and motivation behind these CBDC's, analyse their design characteristics in the light of the framework presented in section 2.3, and interpret the work of these central banks in the context of the financial and banking system implications discussed throughout this dissertation.

6.1 Implemented CBDC – The Bahamian Digital Sand Dollar

The digital sand dollar is a CBDC issued by the Central Bank of the Bahamas (CBoB) on the 20th of October 2020, the first of its kind. Before its issuance, project sand dollar, an initiative responsible for developing and launching the CBDC, was included under the Bahamian Payments Systems Modernisation Initiative, a project founded to modernize the country's payments system to support the development of the economy, of which, among other projects, a CBDC was considered an important tool to achieve said goals (CBoB, n.d.). The project's objectives were to guarantee the access of its population to digital payments and deposit account services, reduce the size of the legal underground economy and promote the digitalization of small and medium size enterprises. Project Sand Dollar contributed to

these objectives by increasing access of digital payment services to the unbaked population of the country and increasing efficiency in payments (CBoB, n.d.). Before issuance, the CBoB selected private sector partners to help manage the digital sand dollar's infrastructure and conducted pilot testing (CBoB, n.d.).

The design of the digital sand dollar, considering the discussions in section 2.3, is outlined below. Firstly, since it is offered via intermediaries, such as PSP's which operate mobile payment wallets and provide customer service (CBoB, n.d.), it is an indirect CBDC. Given that it requires (some) identification (CBoB, n.d.), it is account-based rather than token based. It is also a retail CBDC, i.e. available to the public and non-financial businesses, and inspired on permissioned DLT (transaction validators are selected by the central bank) with PoW (see section 2.2), designed by private sector partner MovMint (Noll, 2024). While it is not remunerated, it is subject to tiered holding limits (CBoB, n.d.). Tier I does not require official identification documents (though it does require some identification, such as a phone number) and has a B$500 holding limit and B$1,500 monthly transaction limit[35]. Tier II requires government-issued identification and contains limits of B$8,000 and B$10,000, respectively, and allows linking to a bank account (as opposed to Tier I). In addition to individual wallets, there are merchant (business) ones, with holding limits of B$8,000 to B$1,000,000 and unlimited transaction limits, which can be accessed after providing the relevant documentation. It is not designed for cross-border use, although the bank is preparing to include this feature in the future (Soderberg et al., 2022).

To obtain and use digital sand dollar, individuals or businesses need to select an authorized financial institution that works in partnership with the CBoB and download a digital wallet via their app with a smartphone, and select the specific wallet tier desired, providing any required identification information (CBoB, n.d.). A physical card option linked to the digital wallet is also available. The user can then use the app to pay for goods and services or make P2P transfers, selecting the receiver's phone number or by scanning a QR code (CBoB, n.d.).

Several insights can be drawn. First, by providing a tier with relatively little identification requirements, the CBoB opted for a tier system that is designed to facilitate

[35] For reference, the Bahamas operates a fixed exchange rate system with the US dollar maintaining a 1:1 parity, and its GDP per capita (PPP) in 2024 was $36,742 according to the World Bank (World Bank, n.d.), https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?locations=BS .

unbanked individuals to access the digital payments system, which reflects the motivation by several developing economies to increase financial inclusion via CBDC's[36]. In the specific context of the Bahamas, as an archipelago in the West Indies with about 700 islands, of which 30 are inhabited, it contains certain segments of the population that live in sparsely populated islands and is thus unprofitable to supply banking services there, with a CBDC being seen as the solution to this problem (Soderberg et al., 2022). In addition, as discussed in section 5.1, by creating transaction data every time a user pays with digital sand dollar, it can increase accessibility to credit facilities as financial institutions may draw upon such data to screen borrowers, helping to increase credit supply to the economy, a benefit noted by the central bank itself[37]. Moreover, the inclusion of holding limits even for wallets with proper identification and its lack of remuneration reflects the concern of the central bank over the effect of a CBDC its banking and financial system (CBoB, 2019), such as disintermediation and bank runs.

Yet the uptake of this new currency has been limited (Noll, 2024). As of December 2023, the number of individual wallets stood at 118,995 with 1,797 merchant wallets, and sand dollars in circulation totalled $1.7 million (CBoB, 2024), less than 1% of (Bahamian) dollars in circulation, and while the number of individual wallets seems large relative to the population (around 400,000), many wallets were opened solely in relation to giveaways and financial incentives designed to increase take up and subsequently became inactive (Branch et al., 2023). The central bank plans to force commercial banks to offer CBDC accounts to leverage their existing client base in order to increase uptake (Howcroft & Jones, 2024). The CBoB has explained the lack of take up due to lack of adoption by businesses and absence of integration with banks (Koonprasert et al., 2024).

[36] This feature is also useful for tourists.

[37] "It also provides an excellent record of income and spending, which can be used as supporting data for micro-loan applications", retrieved from the digital sand dollar website (CBoB, n.d.), https://www.sanddollar.bs .

6.2 CBDC in Preparation – The Eurozone's Digital Euro

The digital euro goes back to 2020, when the European Central Bank (ECB) issued a report on the possible issuance of a CBDC (ECB, 2020). The reasons for issuing it, according to the ECB, include safeguarding the role of central bank money in the economy, increase European strategic autonomy by creating a form of money with governance and infrastructure under European control, and increasing resilience and efficiency in the payments system (ECB, 2023).

After a public consultation and technological experiments, it was decided to move on to the investigation phase in July 2021 with the launch of the digital euro project. This phase, which included 4 progress reports, was responsible for examining the possible design features of the digital euro as well as its distribution (ECB, 2022), which included investigations of possible holding limits, remuneration[38], offline capabilities, privacy features and the role of intermediaries.

In October 2023, the ECB started the preparation phase, which is expected to be completed by November 2025, with two progress reports thus far published[39]. Besides including additional testing of possible design features, the main objectives of this phase are twofold. On the one hand, it is to design and implement the digital euro rulebook, a document which will outline "a single set of rules, standards and procedures to standardise digital euro payments across the euro area" (ECB, 2024a, p. 6), that is, to harmonize standards across the euro area to facilitate intermediaries' access to payment systems outside of their own countries and overcome the current fragmentation of European markets. On the other hand, it has the objective to choose the private sector providers that will design the digital euro infrastructure.

Since the digital euro is still in preparation, its design features have not been ultimately decided, though the ECB, in the various progress reports it has published, has identified several characteristics that are expected to be implemented in the final version. Firstly, the digital euro will involve an indirect scheme, with intermediaries such as banks and other

[38] Which was under consideration at the time.

[39] As of June 9th, 2025.

PSP's managing customer onboarding[40], with users having access to their digital euro both via the apps of their PSP's and a separate digital euro app, which intermediaries may choose to "integrate […] with their own solutions" (ECB, 2023, p. 6). Digital euro accounts are to be funded via transfers of bank deposits or with cash in an ATM. The discussions around the digital euro indicate that will be a retail CBDC, not wholesale, that is, available solely to households, but not financial institutions (ECB, 2023).

Regarding the distinction between account and token-based CBDC, the digital euro appears to be, to some extent, a hybrid model, incorporating some of both features. While in order to open an account an identity would need to be provided, with balances and transactions overseen by intermediaries, making it an account-based system, the offline functionality that the ECB wants to implement features some token-like features. Users would be able to perform P2P transactions or purchase goods and services without validation by a third party (the PSP) via the use of NFC payment technology (see section 2.1), and with the validation of the transaction occurring locally between the two parties, and offline[41] (ECB, 2024a).

When it comes to safeguards, the digital euro would not feature remuneration but holding limits would be applied, with the exact limit to be chosen closer to the issuance date to reflect the prevailing economic situation (ECB, 2024a). This feature is related to another important characteristic of the digital euro, the reverse waterfall: any funds received or disbursed that exceed the limit are to be transferred to, or retrieved from, a linked bank account at a commercial bank (ECB, 2023), thus overcoming the problem of payments that go beyond the holding limit pointed out by Ahnert et al. (2024). In addition, while (non-financial) businesses could receive digital euro payments, they would not be allowed to hold funds in their wallets, with payments flowing to their commercial bank accounts via the waterfall feature (ECB, 2023).

Other attributes include the fact that it would be free of charge, with the ECB covering the costs of issuing and running its infrastructure, as is currently the case with

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[40] Including KYC and AML/CFT measures.

[41] "The payment would be validated directly by two offline devices […] belonging to the two parties involved in the transaction, without the need for a centralised system or third party. Transaction data would not be sent through a network but would remain on the two devices used for the transaction, thereby protecting user privacy" (ECBa, 2024, p. 4). This would require pre-funding the offline account and would be bound by tighter holding and transaction limits.

physical central bank money (ECB, 2023; ECB, 2024a). Additionally, it will contain strong in-built privacy features which, in addition to the privacy provided by offline payments, would see the Eurosystem unable to directly link transactions to individuals using techniques such as message encryption and pseudonymisation (ECB, 2024a). While at this stage the digital euro is designed to be used solely by euro area residents, the ECB is considering extending the availability to non-residents in the future, including to tourists in the euro area (ECB, 2023).

The design features selected by the ECB reflect its preoccupation with the implications of CBDC for the financial system. For example, the use of holding limits, according to the ECB, aims at limiting (but not eliminate) its store of value usage and thus maintain banks' function in credit extension to the economy, as well as safeguard financial stability and monetary policy transmission (ECB, 2024a). This shows the ECB is, on the one hand, conscious of the effects that a CBDC could have for bank funding, while, on the other hand, showing scepticism to a greater role of the central bank in financial intermediation that could follow from a large inflow into CBDC (discussed in section 3.3), aiming to preserve commercial banks' current role. By decreasing the role of the digital euro as a store of value, it seems very likely that bank funding will not be much affected by the issuance of the digital euro, so that fears of disintermediation of banks and bank runs are, at least for now, unwarranted. It also means that it is unlikely that CBDC will be in competition with other safe financial assets as it would lack remuneration and hence its consequences for asset markets discussed in section 5.2.2 would also likely be limited[42]. In addition, the lack of remuneration and offline capability aims at making the digital euro as similar as possible to physical cash (since it also shares these features), reflecting the motivation to use CBDC to combat the decline in the use of central bank money, as well as to minimize its consequences for the financial system (ECB, 2020), as the replacement of physical cash for CBDC has no impact on commercial banks' aggregate balance sheets (see scenario A in section 3.1.1).

Of course, these limits may be more of a precautionary measure by the ECB, to make sure the implementation of CBDC goes smoothly, and thus may remove them in the future

[42] This also applies to the discussions of issuing CBDC against eligible collateral: if holding limits are tight, then the quantity of CBDC in circulation will also be low, and thus so will be central bank purchases of, for example, government bonds.

and aim for a greater use of CBDC in the future, for example, to reap the benefits of a greater central bank role in credit provision. In this scenario, our discussions remain valid.

Going beyond negative impacts, the ECB is also looking to take advantage of the positive impacts of CBDC, for example in the payments system. By offering a low-cost infrastructure to run digital payments on, the digital euro would lower barriers to entry to new entrants in the sector (such as fintech firms), increasing competition, which "would also be advantageous to smaller PSPs that lack the resources to develop their own front-end solutions to distribute digital euro services" (ECB, 2024a, pp. 13-14). In the eurozone context, it would also serve to decrease market fragmentation, since it would provide a common framework for all firms in the sector, an objective of the digital euro rulebook, increasing competition in the eurozone's payments system.

Conclusion

This dissertation's research aim was to examine how might CBDC's impact the financial system, with the analysis indicating that it can have a potentially very large effect. However, many of these impacts are dependent on the potential design characteristics and framework of CBDC that central banks may choose to implement and are subject to the structure of the underlying banking and financial system.

Due to their digital nature, CBDC's may be designed in various ways, which include being directly managed by the central bank (direct CBDC) or by intermediaries (indirect CBDC), available to households and businesses (retail CBDC) or solely to financial institutions (wholesale CBDC), an account or token format, and the featuring of remuneration or holding and transaction limits (Auer & Böhme, 2020; Bindseil, 2019).

The extent of disintermediation of the banking system will depend on the CBDC framework and banks' own responses to its issuance, making it challenging to anticipate such effects. While hard quantitative limits can directly limit outflows, they decrease its utility as a means of payment (Auer et al., 2022), such that holding and transaction limits should be flexible enough to not undermine CBDC's attractiveness for day-to-day use. Banks may increase interest rates on deposits to attempt to retain funding, that is, it can result in greater competition in deposit markets in concentrated sectors (Andolfatto, 2021; Chiu et al., 2023), or attempt to capture (more expensive) wholesale funding, potentially creating more volatility in funding (Group of Central Banks, 2021; Huang & Ratnovski, 2011), and which can give an advantage to bigger banks since they can more easily access it (Whited et al., 2022). Other impacts, such as on bank-risk taking, is even more intricate as it involves many different opposing forces, but it is hard to see how bank profits will not be affected by sizable deposit outflows to CBDC. Bank runs to CBDC will likely be dissuaded by the appropriate deposit insurance (Mancini-Griffoli et al., 2018), however, central banks should align their supervisory framework with the new post-CBDC world, including potentially denying convertibility in crisis times (Kumhof & Noone, 2021).

Moreover, central banks can provide liquidity to banks experiencing outflows, making up shortfalls in deposit funding (Brunnermeier & Niepelt, 2019; Niepelt, 2020). This must be accompanied by revised and tightened supervisory oversight to ensure alignment

between bank incentives and central bank objectives for financial stability. Central banks may also decide to directly participate in financial intermediation, provided investment in the proper infrastructure is made, which would chart new territory for central banking. Due to the lack of experience in this area, it should be approached with caution, to make sure allocative efficiency is not threatened and the central bank's credit allocation is not subject to unwarranted political pressures.

A CBDC would also impact the financial system beyond commercial banks. Non-bank lending has a variety of advantages (Claessens, 2024) which a CBDC issuance can create space for. However, the appropriate regulatory framework should be put in place to enable the development and emergence of this type of funding and mitigate its downsides, especially in the context of the euro area. Other impacts beyond financial intermediation would also be felt. CBDC's have the potential to increase efficiency in the payments system (Dyson & Hodgson, 2016), such that central banks should ensure that CBDC infrastructure is low cost and easy to access by PSP's, in order to spur greater competition in the sector. In contrast, CBDC's can compete with other safe assets and impact yields across the financial system as well as the investment funds that hold them, though these impacts would largely disappear if CBDC is not remunerated.

Internationally, cross-border use of CBDC may, on the one hand, result in increased capital flows and exchange rate volatility (Popescu, 2022), while on the other hand, decrease the costs of cross-border transactions. In this context, cooperation between central banks is crucial to ensure international spillovers do not threaten the soundness of the international financial system.

Real-world schemes of CBDC's provide clues into how these currencies are taking shape in real-life. The Bahamas' CBDC, despite its low uptake, features tiered holding limits and no remuneration, which reflects the CBoB's preoccupation with financial stability, while incentivizing its use within its unbanked population, foreseeing the use of CBDC's as a means to increase financial inclusion and access to credit (CBoB, 2019; CBoB, n.d.). The digital euro, though still in preparation phase, is expected to feature similar safeguards, as the ECB is currently seeking to maintain the role of commercial banks in the economy (ECB, 2024a). At the same time, the ECB aims to use the digital euro infrastructure to increase competition and efficiency in the euro zone's fragmented payments system (ECB, 2024a).

The insights in this dissertation help frame the discussions surrounding CBDC, such as its nature, design, motivation of issuance, and illuminate its potential implications for the financial system. It contextualizes the fears surrounding CBDC, such as disintermediation and bank runs, clarifying the decisions by central banks to roll out their CBDC's in a constrained manner, with sufficient safeguards to allow an orderly transition. It also discusses potential positive effects of CBDC, from increased competition in financial intermediation to greater efficiency in payments systems. Overall, it reviewed its implications for a variety of participants in the financial system, such as banks, non-bank lenders, investment funds, fintech firms and PSP's. This aims to contribute to the existing literature by providing an exhaustive critical review that fully encompassed the financial system, in place of a focus on certain segments.

As things stand, central banks are planning to issue their CBDC's in a precautionary way, with holding limits, no remuneration, and limits to its international usage. This reflects the desire that its rollout is done in a smooth manner. Yet, this does not make our discussions irrelevant: these constraints may be softened or shift over time, especially as CBDC's become established and policymakers become keen to take advantage of their positive aspects, such as increased competition for banks, greater efficiency in the payments system or central bank participation in credit extension. This means that the analysis presented here offers highly valuable insights into CBDC's, as anticipating future impacts to the financial system is crucial to ensure any changes to CBDC's design features do not threaten financial stability. The issues addressed here will continue to inform future debates and policymakers on the appropriate design of these currencies and its impacts.

It is important to acknowledge the limitations of this dissertation. This includes the lack of empirical data which, even though it is inexistent for advanced economies due to CBDC not having been issued, still limits our conclusions due to the speculative and theoretical nature of the discussions, instead of empirical results. Additionally, some of the studies reviewed here feature economic modelling with assumptions that may not be realistic, for instance, by including CBDC characteristics which central banks may not be currently considering, such as remuneration (Bindseil & Senner, 2025). In addition, the cases analysed are confined to certain economic areas (the Bahamas and the euro area) and thus insights from these CBDC's may not necessarily apply to other countries that are considering issuing a CBDC (e.g. China or Sweden). All in all, the lack of use of CBDC's around the world makes

it intricate to form a firm understanding of its final effects on the financial system. Nevertheless, the insights gathered here provide a theoretical framework that is essential to guide research and policymakers on the topic.

While this dissertation presents a comprehensive review into how CBDC connects with the financial system, there are several dimensions where understanding remains limited or unexplored and are thus relevant topics for future research. For example, identifying the impact that CBDC will have amongst banks with different characteristics (e.g. size, funding sources) warrants more research. Additionally, future inquiries could focus on how non-bank lenders may emerge alongside CBDC issuance, how it will affect financial intermediation and interact with CBDC frameworks. Moreover, new studies on CBDC's should be aligned with central banks' plans for their design features, to retain congruency between research and real-life CBDC projects. In addition, theoretical insights into the implications of an increased role of the central bank in financial intermediation, especially via CBDC's, is also warranted.

As digitalization reshapes money itself, CBDC's have the potential to upend, both positively and negatively, the contours of the financial system. While its implementation remains cautious and uncertainty about its impacts persist, an engaged and well-informed discussion is crucial so that any impacts from CBDC's are anticipated and align with a stable and efficient financial system.

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