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The economics of central bank digital
currency

Discussion Papers

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Abstract

This paper provides a structured overview of the burgeoning literature on the economics of CBDC. We document the economic forces that shape the rise of digital money and review motives for the issuance of CBDC. We then study the implications for the financial system and discuss of a number of policy issues and challenges. While the academic literature broadly echoes policy makers' concerns about bank disintermediation and financial stability risks, it also provides conditions under which such adverse effects may not materialize. We also point to several knowledge gaps that merit further work, including data privacy and the study of end-user preferences for attributes of digital payment methods.

JEL Codes: E41, E42, E51, E52, E58, G21

Keywords: Central Bank Digital Currency, Digital Money, Payments, Monetary Policy, Financial Stability.

Non-technical summary

Currently, all major central banks around the world are exploring the case for introducing central bank digital currency (CBDC). Policy makers' interest has been fueled by the secular decline in the use of cash and the proliferation of digital payments, which pose significant challenges to the status quo of the current financial system. Unsurprisingly, the policy debate has sparked interest in the academic community and led to a rapid growth of research on the wider implications of a CBDC introduction.

This paper provides a structured overview of the burgeoning literature on the economics of CBDC. It reviews the developments that have led to the rise of digital money, followed by a synthesis of the various economic motives that have been put forward for the introduction of a CBDC. We point out how network externalities that are present in the use of a medium of exchange are reinforced by the access to data that arise from trading on large platforms. These network externalities could lead to a dominance of BigTech companies in the payments market, providing a motivation for central banks to introduce CBDC.

The paper then proceeds to review the potential implications for two key themes of interest for the central banking community, namely monetary policy and financial stability. We argue that public digital money in form of a CBDC could replace banknotes as the monetary anchor of today's two-layer monetary system and help retaining monetary sovereignty if global stablecoins became widely used. A much-debated issue is privacy in payments, where we argue that market forces on their own are unlikely to lead to an optimal degree of privacy. We then go on to explore the interactions of a CBDC with monetary policy transmission and implementation. The main implications arise from the substitution of bank deposits for CBDC and the resulting changes in banks' funding structure. When issuing a CBDC, central banks need also to be aware of potential consequences for the size and structure of their own balance sheets. Regarding financial stability, a CBDC could – on the one hand – increase the probability of a bank run but might – on the other hand – incentivise banks to offer more attractive deposits, giving rise to a potentially non-linear relationship between CBDC remuneration and bank stability.

The remainder of the paper contains a discussion of key policy issues and challenges such as regulation and incentives for adoption of a CBDC, and highlights a number of takeaways that emerge from the review of the literature.

Importantly, the paper focuses on the topic of a “retail CBDC” accessible to citizens and non-financial firms. It does not touch upon a parallel debate about “wholesale CBDC” intended for use by financial intermediaries.

1 Introduction

Traditionally, interest in the economics of money and payments has been largely confined to a narrow circle of experts in central banking, academia, and the financial industry. This has changed dramatically over the past 15 years or so, as technological innovation is disrupting the market for payments at an unprecedented scale, and the resulting changes are becoming tangible in citizens' everyday lives. Strong growth in e-commerce has led to a decline in the use of cash and increased demand for electronic payments. Technology-driven start-ups ("Fintech") and large digital platforms ("BigTech") are increasingly pushing into a market traditionally dominated by banks and credit card companies. At the same time, the development of distributed ledger technology (DLT) enables the decentralized settlement of electronic transactions, which has spurred the creation of fiat cryptocurrencies and stablecoins.

These developments have inspired central bankers to explore the merits of introducing a digital version of cash: central bank digital currency (CBDC). Notably, this debate has intensified considerably in recent years as policy makers have become unsettled by prospects for abrupt and potentially irreversible changes to the financial system due to the existence of strong network effects in both payments and digital services. Although ultimately not realized, the initial Libra proposal by Facebook (now Meta) was widely perceived as a significant wake-up call and led to an intensification of research efforts throughout the central banking community. According to a recent survey, 90% of 81 respondent central banks were actively investigating the potential for a CBDC at the end of 2021 (Kosse and Mattei, 2022).

This paper provides a structured overview of the burgeoning literature on the economics of CBDC. It starts out with a review of the underlying economic drivers of the rise of digital money, namely the digitalisation of economic activity and, consequently, payments. We then discuss how these developments give rise to concerns about the role of public money as anchor for the two-layer monetary system, monetary sovereignty, privacy in payments, and other frictions that motivate central banks to consider the issuance of CBDC.

Next, we study the implications of a CBDC introduction for the financial system. We first consider potential changes to the transmission and implementation of monetary policy, with a particular focus on the role of banks due to their central role in money creation and credit supply. We then discuss the consequences for financial stability, where we distinguish between effects affecting the asset and liability sides of intermediaries' balance sheets, as well as the implications for financial stabilization policies. For both monetary policy and financial stability, we also discuss the role of proposed safeguards in the CBDC design that aim to mitigate potential adverse effects.

The last section discusses several policy issues and challenges. First, we ask whether some of the key objectives that CBDCs aim to address could also be achieved through regulatory action. Then, we consider challenges related to end-user adoption (e.g. by consumers and merchants) on the basis of a pre-existing literature on the economics of payment instrument choice. And finally, we point towards several political economy issues.

In the conclusion, we highlight a few selected insights that arise from our review of the literature. While academics acknowledge policy makers' concerns about the potentially adverse effects of a CBDC issuance on bank lending and financial stability, they also point to mitigating forces. For example, credit supply may ultimately benefit from more competitive deposit markets. Similarly, more attractive deposit contracts could help limit the risk of bank runs. We also point to promising avenues for future research. Privacy in payments is a complex issue waiting to be explored further. And the proliferation of electronic payments raises interesting questions concerning the preferences of end-users over the various attributes offered by new forms of digital money.

Our paper focuses on the economics of “retail CBDC”, a digital central bank liability that is accessible to citizens and non-financial firms. We do not touch upon a parallel debate about “wholesale CBDC” intended for use by financial intermediaries because it will entail a less significant change to the status quo of the financial system.¹ While we discuss technological innovations such as distributed ledger technology and the relationship between CBDC and stablecoins, our paper largely steers clear of the topics of cryptocurrencies and decentralized finance (“DeFi”).

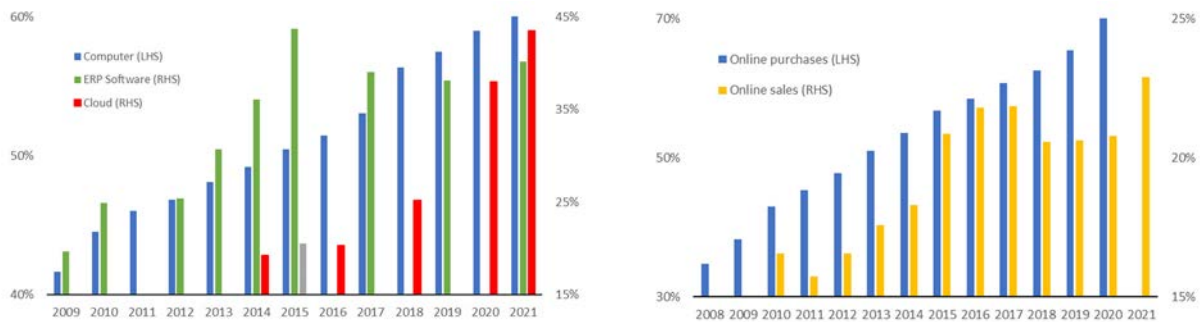
2 Digitalisation in business and payments

This section provides an overview of the key drivers that have led to the debate about the potential introduction of central bank digital currency. We first review how the ongoing digitalisation is reshaping the economy, and then discuss the rise of digital money.

2.1 The economy in the information age

The digitalization of the economy is progressing at break-neck speed. Firms are dramatically increasing investment into information and communication technologies (ICT) to reap the associated productivity gains (Figure 1A). At the same time, the distribution of goods and services is steadily shifting towards online channels (Figure 1B).

¹ Broadly speaking, wholesale CBDC and central bank reserves operate in very similar ways. However, wholesale CBDC may provide new benefits such as improved cross-border settlements or programmability, see BIS (2021a).



Panel A: ICT usage

Panel B: E-commerce

Figure 1. The left panel (A) depicts various measures of ICT usage for the euro area over time. “Computer” refers to the percentage of employees that use a personal computer at work. “ERP software” denotes the share of firms that use Enterprise Resource Planning software. “Cloud” refers to the percentage of firms using cloud computing services. Countries: DE, FI, FR, GR, IE, IT, LU, NL, PT, ES. Source: OECD. The right panel (B) illustrates the growth in e-commerce for the euro area over time. “Online purchases” represents the percentage of individuals that have purchased at least one item online over the last 12 months. “Online sales” refers to the share of firms with online sales. Countries: AT, BE, DE, EE, FI, FR, IE, GR, ES, IT, CY, LV, LT, LU, MT, NL, PT, SI, SK. Source: Eurostat. All series are aggregated using GDP-weights.

The ongoing digitalization is leading to rapid changes in the overall structure of the economy. Two driving forces stand out: digital platforms as dominant business model, and an increasing role for intangible inputs such as data and software. While both promise significant efficiency gains, concerns are mounting that they also give rise to market power and enable anti-competitive practices.

Digital platforms such as Google, Amazon, or Facebook are the signature business model of the digital economy. They operate as *two-sided markets*, which entails two key features (see Rysman, 2009). First, they intermediate transactions between two groups of agents. Second, a *network externality* is present: the decisions of each group of agents affect those of the agents on the other side of the platform. For example, sellers will find an online marketplace more attractive if more buyers are present, and vice versa.²

Network externalities are a source of market power and thus play a key role for platform pricing and competition.³ Platforms aim to strengthen network externalities by creating closed ecosystem (so-called “walled gardens”) with the aim of locking in one side of the market, which enables them to charge monopoly prices to the other side. In the extreme, this can give rise to a *winner-takes-it-all* outcome with a single dominant platform in a particular market segment.⁴

² In addition to such a *cross-side* network externality, a *within-side* network externality may also exist. For example, users of social networks derive greater utility if more of their friends form part of the network.

³ For example, the optimal price structure is asymmetric, with lower (often zero or even negative) prices prevailing on the side of the market where user demand is more elastic (Rochet and Tirole, 2003; Armstrong, 2006).

⁴ Unlike in one-sided markets, a dominant player can - in principle - be beneficial to consumers because it allows to reap the benefits associated with network externalities, which can compensate for the potentially higher prices set by the platform.

Beyond the dominance of digital platforms, an increased role for intangible inputs such as data and software are a defining feature of the digital economy. This gives rise to significant scale economies with increased fixed costs and reduced marginal costs, which favors large firms (Farboodi et al., 2019; Farboodi and Veldkamp, 2021). The resulting shift in the economy’s cost structure leads to a competitive edge for early technology adopters. While this boosts productivity in the short run, it deters entry by new firms and thus leads to lower growth in the long run (De Ridder, 2021).⁵

Unlike traditional inputs, data is non-rival: It can be used multiple times, or by multiple parties (Jones and Tonetti, 2020). Accordingly, a broad use of data on consumer preferences promises large social gains through more efficient matching and better goods and services. However, private incentives typically lead to data hoarding as firms aim to exert market power and fend off competitors.⁶ Since network externalities and private access to data can be mutually reinforcing, such concerns become particularly acute in the case of digital platforms.

Empirical work supports the overall narrative of increasing concentration and market power. The evidence shows that mark-ups are rising (De Loecker et al., 2020) and a handful of “superstar firms” have emerged as dominant (Autor et al., 2020).⁷ The breathtaking stock market performance of large technology companies (sometimes referred to as “BigTech”) over the past decade speaks for itself (Figure 2).



Figure 2. This Figure depicts the cumulative stock market performance of the S&P 500 Index and an equal-weighted portfolio of five major technology stocks (“Big Tech”): Alphabet (Google), Amazon, Apple, Microsoft, and Meta (Facebook). Both series are normalized to 100 at the beginning of the sample period (May 2012 – April 2022). Data source: Refinitiv.

⁵ Aghion et al. (2022) reach broadly similar conclusions in a model based on the expansion of superstar firms.

⁶ See, e.g., Bergemann et al. (2015), Jones and Tonetti (2020), Hagiu and Wright (2021), Ichihashi (2020), Kirpalani and Philippon (2022), and Prüfer and Schottmüller (2021).

⁷ While most the facts have established based on US data, Cavalleri et al. (2019) document relatively stable markups for the four major EU economies.

2.2 The transformation of money and payment services

Money is crucial to economic activity because it enables the efficient exchange of goods and services. Without a widely accepted medium of exchange, transactions are limited to barter and credit arrangements, which can break down unless there is trust supported by long term relationships, or perfect commitment.

Different types of money co-exist in our current monetary system, and there is a rather strict separation in their creation. Physical money – cash – is typically only issued by the central bank.⁸ It is public money in the sense that it is a direct liability of the monetary authority. By contrast, digital money available to the general public is created by commercial banks, usually in the form of bank deposits.⁹ It is thus private money.

In practice, many citizens are not aware of any formal distinction between public and private (bank) money; they are deemed as equivalent in everyday use. However, this was not always the case. For example, private banknotes issued during the “Free Banking Era” in the United States typically traded at a discount depending on the issuer’s creditworthiness.¹⁰ Today, banks are subject to a carefully designed framework of bank regulation and supervision which aims to enforce prudent behaviour. In combination with deposit insurance, this ensures that retail deposits are perceived as perfectly safe, and equivalent to public money.

To operate efficiently, a digital economy requires digital money. Since more and more business is conducted online, cash is losing its appeal as efficient means of payment. Consistent with this view, Panel A of Figure 3 shows that the number of card payments in the euro area has increased more than four-fold over the past two decades. Over the same time, cash withdrawals at ATMs have fallen by around 20%, with evidence of an accelerating decline over recent years.¹¹ Panel B draws on data from payment diaries in Germany and the Netherlands and shows that the use of cash as means of payment (measured as percentage of transactions settled in cash) has declined strongly over the

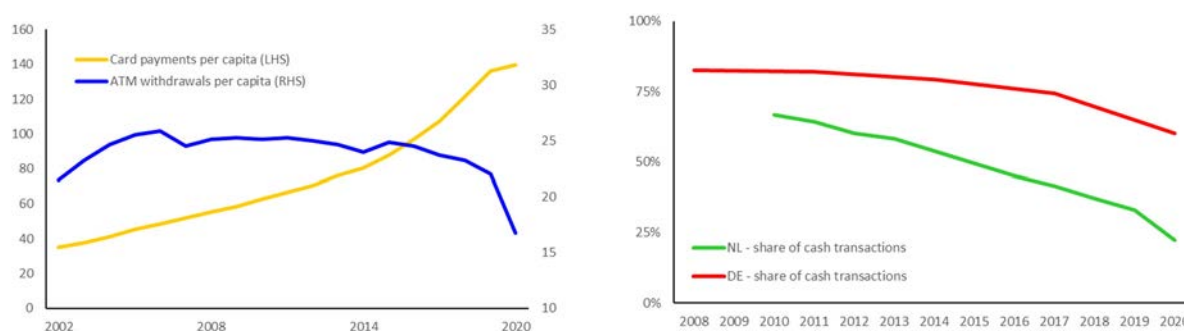
⁸ One rare exception is the UK. Under the Banking Act 2009, certain commercial banks in Scotland and Northern Ireland are permitted to issue physical banknotes. However, these must be fully backed by banknotes issued by the Bank of England.

⁹ Note that public digital money exists in the form of central bank reserves. However, these are only available to financial institutions with a reserve account.

¹⁰ See Warren Weber’s database on historical discounts of banknotes at <https://researchdatabase.minneapolisfed.org/collections/2i62s4898?locale=en>

¹¹ Note that ATM withdrawals can be motivated by the need to obtain a means of payment or a store of value. The latter becomes economically more relevant in a negative interest rate environment.

past decade.¹² It also reveals some significant cross-country variation, as the prevalence of cash payments differs substantially across those two economies.



Panel A: Card payments and ATM withdrawals (euro area)

Panel B: Share of cash payments (DE and NL)

Figure 3. The left figure (A) depicts the evolution of card payments and ATM withdrawals per capita for the euro area over the period 2002-2021. Countries: AT, BE, CY, DE, EE, ES, FI, FR, GR, IE, LU, LV, NL, PT, SI, SK. Source: Eurosystem. The right figure (B) plots the share of retail payments paid in cash, based on data from retail payment diaries in Germany and the Netherlands. Source: Bundesbank and De Nederlandsche Bank / Betaalvereniging.

Despite its growing dominance over cash, today’s digital money faces challenges. The current system of interbank payment rails has not fully caught up with technological change. Moreover, from the perspective of consumers, settlement remains slow: bank transfers, even within jurisdictions, continue to take 1-2 business days. More generally, retail payment systems are highly fragmented, and the development and adoption of instant payment systems continue to proceed at a muted pace.¹³ While credit cards are well suited for the requirements of e-commerce, especially across borders, they remain expensive for merchants due to the dominance of a small number of card networks. Moreover, they ultimately also rely on the same legacy settlement systems.

The lack of innovation among incumbent institutions has created opportunities for market entrants. This has allowed new payment service providers to capture a significant and growing share of the market for online retail payments. Their success has been enabled by the ability to bundle digital payments with other services, including online marketplaces (Paypal/Ebay, Alibaba/Alipay, Amazon), lending (Klarna, Affirm), social networking (WeChat), ride-hailing (Go-Jek), and telecommunication (ApplePay, GooglePay, M-Pesa).

Although the market for retail payments has undergone significant change, it continues to rely to a large extent on pre-existing infrastructures. Frequently, new payment solutions such as mobile

¹² Card payments tend to be for higher amounts than cash payments. Nevertheless, the pattern over time is qualitatively similar when considering payment values instead of the number of payments.

¹³ The Eurosystem launched its TARGET Instant Payment Settlement (TIPS) platform in November 2018, which enables instant payments 24/7/365. So far, the usage of TIPS has been limited. The US Federal Reserve’s FedNow Service is planned to go live in 2023.

wallets merely embed traditional products such as credit cards or deposit accounts into a new front-end to increase user convenience and capture the client interface (together with the underlying data). Moreover, the customer balances of non-bank payment providers are ultimately “mirrored” as deposits in the traditional banking system.¹⁴ While the internalization of payment flows within these new payment networks generates significant efficiency gains, a lack of interoperability gives rise to the need for multi-homing and a more fragmented payment system.

More fundamental change is looming with the advent of distributed ledger technology (DLT). Since digital money only exists in the form of computer code, it can in principle be duplicated and spent more than once (the so-called “double-spend” problem). In the traditional monetary system, this problem is mitigated by certification through trusted third parties such as banks. By contrast, DLT enables the direct exchange of digital claims (often referred to as “tokens”) without the need for a trusted third party. The system relies on an immutable public transaction record (the “ledger”), which is maintained on different nodes of a peer-to-peer network and updated regularly by means of a consensus protocol. In the extreme case of full decentralization with a “permissionless” ledger, anyone who forms part of the network can certify transactions. Since the ledger’s reconciliation process involves a large network of nodes, it is prohibitively expensive to “double spend”.

DLT provides the basis for the development of cryptocurrencies, which could be used as a digital means of payment and support efficient contracting and decentralized settlement (including “smart contracts”). However, they are subject to significant challenges. In particular, fiat cryptocurrencies such as Bitcoin are subject to significant price volatility, which renders them inadequate as means of payment. Stablecoins – cryptocurrencies whose value is backed by a pool of reserve assets – have been proposed as a potential solution to this problem. However, the recent failure of the poorly designed stablecoin “Terra” shows that investor trust in such arrangements can deteriorate quickly, and also spill over to other stablecoins.

Moreover, the full decentralization of cryptocurrencies comes at the cost of limited scalability and an excessive environmental footprint for consensus mechanisms such as “proof-of-work”. This makes them particularly unattractive for retail payment systems which require a very large

¹⁴ Regulation typically requires non-bank providers of electronic money to hold customer balances in the form of bank deposits, and segregated from other assets. Depending on the jurisdiction, customer balances may enjoy the benefits of pass-through deposit insurance. Moreover, some payment providers have acquired a fully-fledged banking license to reap the benefits of offering additional financial services (for example, PayPal’s European subsidiary acquired a banking license in 2007).

“through-put”.¹⁵ This issue can be addressed by moving away from a fully decentralized model towards a permissioned DLT where only specific network nodes can update the ledger. Facebook’s Libra proposal, in particular in its revised version, is a particular example in this direction (Libra Association, 2020).¹⁶

The ability to bundle digital payments and services puts BigTech in a unique position to play a major role in the market for payments. In particular, the strong network externalities in both digital platforms and payment services create the scope for dominance by a small number of digital money issuers. These prospects have – at least in part – inspired a debate among central bankers about the potential benefits of introducing public digital money in the form of central bank digital currency.

3 Motives for the introduction of central bank digital currency

In this section, we highlight the key underlying motives for the issuance of “digital cash”. We first discuss the role of public money as a monetary anchor against the background of an increasingly cashless world. We then examine monetary sovereignty, which was catapulted to the forefront of the debate by the publication of the first Libra White Paper in 2019. We proceed to considering the role of privacy in payments, followed by a discussion of how CBDC can address frictions in the markets for payments and financial intermediation, among other potential benefits.

3.1 Public money as monetary anchor in a digital world

Our current monetary system is based on the co-existence of public money (“cash”) and private commercial bank money. Quantitatively, private money dominates the financial system. In the euro area, overnight bank deposits currently account for more than 85% of total money supply (as measured by the narrowest monetary aggregate M1). However, public money is crucial to the functioning of the two-layer monetary system. Due to its nature as a central bank liability, it is the safest form of money, and thus acts as an anchor for the monetary system (see Panetta, 2021, and Brunnermeier and Landau, 2022).

¹⁵ According to bitcoin.com, the Bitcoin blockchain records between 3 and 7 transactions per second. By contrast, the Visa card network claims a capacity of 65,000 transactions per second. See <https://www.visa.co.uk/dam/VCOM/download/corporate/media/visanet-technology/aboutvisafactsheet.pdf>.

¹⁶ Another example is the proof-of-stake consensus protocol, which selects validators in proportion to their stake (i.e. holdings of the relevant cryptocurrency). Buterin (2021) suggests that decentralized settlement creates a trilemma between decentralization, security, and scalability. See Auer et al. (2021b) for a formal analysis of the optimal ledger design in this context.

In the eyes of the consumer, commercial bank money is widely regarded as equivalent to public money. The combination of banking supervision and regulation, deposit insurance, and the central bank as lender of last resort ensure that it can always be converted, at par, into cash. The public safety net guarantees that bank deposits satisfy the “no questions asked” principle and can act as an effective medium of exchange.¹⁷

The ongoing digitalization of the economy poses a formidable challenge to the status quo. As the use of cash is declining, the promise of convertibility at par becomes less and less meaningful. To ensure that public money can perform its function as anchor of the monetary system, it must be widely accessible and used.¹⁸ Accordingly, a digital update of cash in the form of CBDC could help ensure that the two-layer system of public and private money can prevail in the future.

3.2 Retaining monetary sovereignty

Monetary sovereignty refers to the supremacy of domestic currency for fulfilling the three functions of money (unit of account, medium of exchange, store of value) in an economy. Whenever foreign currency takes on a significant role for at least one of these functions, monetary sovereignty is limited. This is often referred to as “currency substitution” or “dollarization/euroization”. One example is Montenegro, where the euro is the official currency, but the domestic central bank is not part of the Eurosystem.¹⁹

Brunnermeier et al. (2019) warn that the rise of digital money could threaten monetary sovereignty. In the spirit of the original Libra proposal, dominant platform operators may strive to bundle their digital services with payment services. By exploiting their large customer base, they may quickly become dominant issuers of private digital money.²⁰ Once widely accepted as medium of exchange, these private digital currencies may also become enshrined as unit of account in contracts within the realm of their ever-expanding ecosystems, and possibly beyond.

This is consistent with the model of Doepke and Schneider (2017), where an economy’s dominant unit of account is determined by agents that are large and generate lots of payments. This has ensured that government-issued currency, in which government debt is denominated, has emerged as the dominant unit of account in advanced economies. The introduction of a CBDC could ensure

¹⁷ The “no-questions-asked” principle requires money to be accepted at par without due diligence. See Holmstrom (2015) and Gorton and Zhang (2021).

¹⁸ However, Lagos and Zhang (2019) show that monetary policy can still have real effects in an almost cashless economy.

¹⁹ A milder case is Poland, where around 50% of mortgage loans outstanding in 2013 were denominated in foreign currency (Brzoza-Brzezina et al., 2015).

²⁰ See Guennewig (2021) for a model with currency-issuing firms.

that public money remains used in practice, and thus help ensuring that it retains its unit-of-account status.

The loss of monetary sovereignty can entail significant costs.²¹ First, it limits the effective conduct of monetary policy. Monetary policy transmits to the economy because prices are sticky in terms of the domestic currency. This is crucial for a monetary expansion to generate an increase in output rather than just a bout of inflation (Gali, 2015). If prices are quoted in a different unit of account, the transmission of monetary policy is impaired. Moreover, Benigno et al. (2022) argue that the presence of alternative means of exchange in the economy, such as cryptocurrencies and private digital currencies, constrains monetary policy. They find that, for public money to be used in exchanges rather than hoarded, the central bank may not set its policy interest rate above the return on the alternative means of exchange, although this may be desirable to control inflation.

Limited monetary sovereignty also gives rise to financial stability risks. In particular, it impairs the central bank's ability to act as "lender of last resort". Theoretically, the monetary authority can "print" unlimited amounts of the domestic currency to support financial institutions in distress (Skeie, 2008; Allen, Carletti and Gale, 2014). However, such liquidity support is no longer available if liabilities are denominated in foreign currency, which increases the risk of bank runs (even for solvent institutions). Consistent with this mechanism, Levy-Yeyati (2006) shows that dollarized economies are exposed to a greater risk of financial crises.

The reach of large digital ecosystems is global. Accordingly, any digital currency issued by "BigTech" would have an international flavor and its use would transcend national borders, such as the initial Libra proposal (Libra Association, 2019). Accordingly, the threat of "digital dollarization" is particularly acute for open economies with a significant reliance on foreign digital players (Brunnermeier et al., 2019). The need to fend off competition for public money from abroad may pose an additional challenge since it may limit the ability to use domestic regulatory tools. This is vividly illustrated by ongoing transatlantic disagreements concerning the regulation of large US-based digital platforms.²²

3.3 Preserving privacy

The concept of privacy spans various dimensions, depending on the context or subject matter. Economists, however, typically focus on its informational aspects (Acquisti et al., 2016). From this

²¹ Limited monetary sovereignty can be beneficial in economies with high inflation (Barro and Gordon, 1983) or poor bank supervision (Gale and Vives, 2002).

²² See "US warns EU against anti-American tech policy", Financial Times, June 15, 2021.

perspective, Westin's (1967) classical definition is useful, according to which privacy is "the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated to others".

The proliferation of personal data as lubricant of the digital economy gives rise to privacy concerns. While user awareness of data collection efforts by technology firms was low in the early days of the internet, sentiment has shifted markedly in recent years. The results from the Eurosystem's public consultation on a digital euro suggest that consumers have become sensitive to the use of data derived from digital payments.²³ This raises two important questions. First, what level of privacy should electronic payments offer? And second, can we trust the market to provide digital money with adequate levels of privacy, or is there a need for policy intervention?

To answer the first question, one must first establish reasons for people to demand privacy in payments. One set of motives includes illegal activities such as drug trafficking, tax evasion, arms trade, etc. To combat those, commercial banks are subject to strict anti-money laundering and "know your customer"-regulations.²⁴ It is crucial that innovative digital means of payments are compliant with these safeguards.

Abstracting from illicit behavior, people may also value privacy in payments for legitimate reasons. Kahn et al. (2005) argue that the privacy provided by cash helps to mitigate moral hazard issues (modelled as the risk of theft). Ahnert et al. (2022) develop a related argument in a theoretical model that captures key features of the digital economy. They study the joint choice of payment methods and distribution channels by merchants in need of financing. Online distribution generates high sales but requires the acceptance of digital payments. This provides information to the monopolist bank and exposes the merchant to rent extraction. While offline distribution results in lower sales, it allows the merchant to accept cash and hide some of the proceeds from the bank. In some cases, the merchant will opt for cash because the associated value of privacy exceeds the gains from more efficient distribution.

Importantly, Westin's definition of privacy also involves an element of control ("determination"). While the withholding of information can be economically efficient in some settings, its disclosure can be efficient in others (Acquisiti et al., 2016). Consistent with this view, Ahnert et al. (2022) show

²³ 43% of all respondents named privacy as the most important feature (European Central Bank, 2021). It is important to note, however, that the survey was not representative.

²⁴ They also motivate upper limits on cash payments in many countries, and the discontinuation of the 500 EUR bill by the Eurosystem. See "ECB ends production and issuance of €500 banknote", ECB press release, 4 May 2016.

that digital payments with optional data-sharing features can increase welfare. When borrowers face multiple potential lenders, they will want to reveal their type to all of them in order to reap the benefits from competition. By contrast, they may prefer to stay anonymous when facing a monopolist, as discussed previously. This inverse relationship between the value of anonymity and the degree of credit market competition is illustrated in Figure 4.

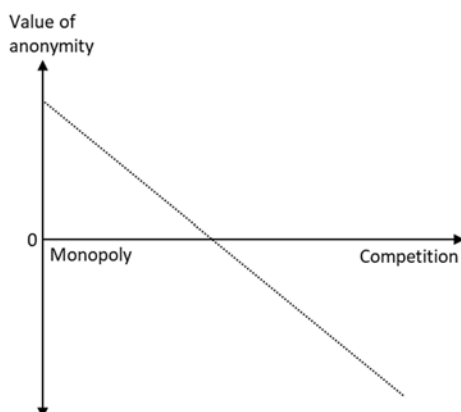


Figure 4. This Figure illustrates the relationship between the value of privacy (vertical axis) and the degree of competition in financial intermediation (horizontal axis) in the model of Ahnert et al. (2022).

The perception that data hoarding by private entities presents an obstacle to innovation and competition is reflected in several recent policy and infrastructure initiatives aimed at promoting data-sharing and interoperability in the digital world. For example, the EU’s Digital Markets Act aims at reducing exclusive control of data collected by digital platforms.²⁵ And Stack India, a major digital infrastructure project in India, aims to build an integrated platform for digital identities, payments, and data sharing.²⁶

We next turn to the question whether one can rely on market forces to satisfy the demand for digital money with socially desirable levels of privacy. The analysis by Garratt and van Oordt (2021) answers this question with a resounding “No”. Their model rests on the observation that consumers share certain observable attributes that are related to their willingness to pay. Accordingly, the collection of payments data from current customers enables merchants to engage in price discrimination against future customers. While agents can protect their privacy at a cost, they only reap part of the social benefit since they may not return to the same merchant. Accordingly, there is too little privacy protection in equilibrium, which results in a welfare loss. This is the case of a classic externality that calls for policy intervention.

²⁵ See [https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690589/EPRS_BRI\(2021\)690589_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690589/EPRS_BRI(2021)690589_EN.pdf)

²⁶ See www.indiastack.org.

The so-called “privacy paradox” raises additional concerns. While consumers tend to attribute a high importance to privacy in surveys, they tend to give away their data for free, or in exchange for very small rewards in practice (e.g. Norberg, Horne and Horne, 2007; Athey, Catalini and Tucker, 2017, Chen et al., 2021). Analyzing the roots for this apparent dichotomy, researchers point to various contributing factors such as asymmetric information, bounded rationality, and heuristics in decision-making (Acquisti et al., 2016). From a public policy perspective, these observations warrant further scepticism concerning the ability of market forces to reach efficient levels of privacy protection.

3.4 CBDC as a tool to address market imperfections

Existing research shows that a retail CBDC could lead to better economic outcomes by reducing pre-existing market imperfections. The most prominent examples in this direction are inefficiencies in payment services and frictions in the financial intermediation process. However, the reach of CBDC potentially extends further, as we shall see below.

First, a retail CBDC could help reduce the cost of making payments. Williamson (2022a) and Keister and Sanches (2022) study settings in which means of payment are not perfectly substitutable, and agents use both currency and bank deposits. The introduction of CBDC as an additional means of payment can increase welfare by lowering the liquidity premium on bank deposits. Another channel for improving payment efficiency could be a reduction in the cost of making cross-border payments (BIS, 2021a), which have experienced considerable growth due to increased travel and remittances.²⁷ At the same time, cross-border payments are often very expensive, which is often blamed on limited competition. Most CBDC designs are at the national (or currency-union) level, but there are efforts (e.g. at the G20 level) to link such schemes through multi-CBDC arrangements (Auer et al., 2021a). This could reduce the effective cost of making cross-border (and cross-currency) payment, both by offering a new service to consumers and by introducing competition among financial intermediaries.²⁸

Second, a CBDC could address frictions in financial intermediation, such as market power in deposit markets, moral hazard, impediments to liquidity provision, and information flows to policy makers. Andolfatto (2020) and Chiu et al. (2022) show that the introduction of CBDC reduces the effective market power of banks in deposit markets by providing an outside option to depositors. This forces banks to compete and raise deposit rates. Moreover, to the extent that (remunerated) CBDC induces

²⁷ Remittances alone were 720 billion USD in 2019 (BIS, 2021a). Moreover, the cost of remittances can be high: a 140 EUR payment from Germany to India incurs a fee of 0.5%-3% (Bindseil and Pantelopoulos, 2022).

²⁸ Part of the cost of cross-border payments comes from AML/CFT regulation, which is not directly related to the payments technology.

depositors to substitute away from bank deposits, the moral hazard friction of the bank is reduced and welfare increases (Williamson, 2022b).

Keister and Monnet (2022) show that CBDC can also improve the information flow to policymakers (such as the lender of last resort) and thus improve the efficiency of interventions. A common concern is that CBDC provides a safe alternative to bank deposits and thus induces depositors to withdraw, which increases bank fragility (see Section 5). Since withdrawals are converted into CBDC during a bank run, the central bank learns about the state of the economy and responds more quickly. This reduces costly liquidation and the misallocation of resources. This information channel reduces the ex-ante incentives of investors to withdraw, so that CBDC can have a beneficial impact on bank stability.

A CBDC may also improve the liquidity transformation services available to consumers (Fernández-Villaverde et al., 2021). If bank runs are possible, CBDC holdings are superior to bank deposits because the central bank (i) cannot be forced into liquidation and (ii) is better than a commercial bank at committing to illiquid investments. Effectively, the central bank takes over as financial intermediary and offers more liquidity to consumers than commercial banks could.

Finally, a CBDC may also have other benefits outside the financial sector. For example, Brunnermeier and Payne (2022) develop a model where digital platforms issue tokens as a means of payment and extract rents (e.g., fees or seigniorage). Customers accept tokens because of a network externality: using the token to sell today is acceptable because it can be used in the future to buy. CBDC, as widely accepted means of payments, competes with the private tokens and reduces platforms' market power.

Similarly, a CBDC introduction may allow governments to improve their control over payment infrastructures. This may be particularly valuable if the current system is dominated by foreign entities, which is the case for the European Union at the moment.²⁹ Further, a CBDC may provide a more efficient channel for governments to disburse fiscal transfers directly to citizens (unlike mailing cheques). Additional features such as programmability may enhance the efficiency of fiscal policy, for example through transfers with an expiry date that yield an increased marginal propensity to consume in crisis times.³⁰

²⁹ Another political economy consideration is how CBDC issuance and its effect on the size of the balance sheet may affect central bank independence (*vis-à-vis* the political system) and trust in the public institution (*vis-à-vis* consumers and citizens).

³⁰ For an analysis of digital cash with an expiry date to facilitate consumer loss recovery, see Kahn, van Oordt and Zhu (2021). For the role of programmability for monetary policy, see Davoodalhosseini (2022).

Finally, CBDC has been lauded as an opportunity for financial inclusion. However, survey evidence suggests that the share of unbanked households in the euro area is less than 5% (Ampudia and Ehrmann, 2017). This suggests that the resulting benefits may be relatively small, at least compared to those expected for developing economies (Boar and Wehrli, 2021).

4 Implications for monetary policy

This section studies the implications of a potential CBDC introduction on monetary policy. We first examine the effects on the transmission of monetary policy through the credit channel. We then discuss the role of a remunerated CBDC as a tool for monetary policy, and potential challenges for monetary policy implementation.

4.1 The credit channel

The credit channel places banks at the heart of the monetary policy transmission mechanism. Since a CBDC can be considered as an alternative to bank deposits for households and firms, it is likely to affect the liability side of banks' balance sheets. This, in turn, may affect the supply of credit and thus the transmission of monetary policy.

One can differentiate between three determinants of CBDC's effect on credit: the impact on banks' funding costs, the impact on their capital, and changes to potential synergies between different bank activities. For the first two channels, the effect crucially depends on banks' response to the prevailing market structure in terms of competition and market discipline. We discuss these issues in turn.

The analysis by Keister and Sanches (2022) is consistent with the widespread concern among policy makers that a CBDC could reduce bank credit supply through "disintermediation" (e.g. Bindseil, 2020). In their model, banks raise funds in a perfectly competitive deposit market. In this setting, the introduction of a CBDC crowds out deposits, raises banks' funding costs, and leads to a decline in bank lending. While Agur et al. (2022) study a slightly different framework, they also assume a perfectly competitive deposit market and come to broadly similar conclusions. These results raise the question whether the central bank could close banks' funding gap through lending operations. This is formally examined by Brunnermeier and Niepelt (2019), who provide conditions for CBDC neutrality in this context.

Crucially, models with imperfect competition in deposit markets come to different conclusions. In Chiu et al. (2022) and Andolfatto (2021), market power enables banks to artificially restrain deposit

supply and keep funding costs low. In this setting, a remunerated CBDC presents consumers with a potential outside option, and thus forces banks to compete more fiercely by raising deposit rates. As long as the CBDC remuneration is not too high, this increases deposit volumes and, ultimately, bank lending.³¹ This mechanism is consistent with empirical work which shows that banks increase deposit rates significantly in response to greater competition (Drechsler et al., 2017). Garratt and Zhu (2021) study the resulting implications in a setting with heterogeneous banks. Since deposits in smaller banks provide less convenience to depositors (e.g. through smaller branch and ATM networks), their deposit base is more vulnerable to an increase in CBDC remuneration. This may lead to a more concentrated banking sector.

The second key factor affecting the effects of CBDC on credit supply is bank capital. Banks hold equity to comply with regulation (Van den Heuvel, 2008) and to align the incentives of owners and managers through “skin in the game” (Gertler and Kiyotaki, 2010). Hence, an insufficient level of capital constrains bank lending.³² The empirical evidence suggests that banks predominantly accumulate capital through retained earnings (Cohen, 2013). However, the effect of CBDC on banks’ profit-retention decisions is ambiguous. On the one hand, CBDC is likely to put pressure on banks’ profits through a loss of market power in deposit markets, which leaves fewer earnings to retain. On the other hand, the ability of bank creditors to switch from bank debt to perfectly safe CBDC can force banks to compete on safety, and thus sharpen their incentives to accumulate capital. This can induce banks to retain a larger share of their profits. The latter effect is likely more powerful in a scenario in which CBDC leads to a shift in banks’ funding mix towards more uninsured debt, which is particularly associated with market discipline (Calomiris and Kahn, 1991; Diamond and Rajan, 2001).

Banks bundle multiple financial activities under one roof because of the existence of synergies. A classic example are the synergies between deposit taking and lending through credit lines (Kashyap et al., 2002). Since deposit withdrawals and credit-line drawdowns are imperfectly correlated, the joint provision of both services enables banks to economize on costly liquid asset holdings. Building on this intuition, Piazzesi and Schneider (2020) show that a CBDC-induced decline in deposit funding implies a loss of synergies and thus a decline in credit provision.

Banks also reap synergies between deposit-taking and lending in their management of interest rate risk. In particular, since deposit rates are sticky (Neumark and Sharpe, 1992; Driscoll and Judson,

³¹ In Whited et al. (2022), banks exert market power, but also face an external financing friction when raising wholesale funding. In this environment, a CBDC leads to a moderate decline in bank lending.

³² Eren et al. (2021) argue that CBDC issuance allows banks to engage in more productive lending per unit of capital. As the central bank balance sheet absorbs more relatively safe assets (e.g. government bonds or mortgage-backed securities), this frees up space on bank balance sheets for business loans.

2013), increases in interest rates only translate gradually into higher interest expenses for banks, if at all. The long effective duration of deposit funding allows banks to insure borrowers against interest rate risk through long-term fixed-rate loans without incurring exposure to interest rate risk (Drechsler et al., 2021; Hoffmann et al., 2019). If a CBDC renders deposit markets more competitive, it may increase banks' exposure to interest rate risk (Whited et al, 2022).³³

4.2 CBDC remuneration as monetary policy tool

Major central banks have expressed the view that the use of CBDC as a monetary policy tool is not the main focus of their explorations. Accordingly, the introduction of a CBDC aims to complement cash, not to replace it (Group of Central Banks 2020). While this is often also understood to mean that CBDC should be available like banknotes, i.e. supplied elastically and without remuneration, it need not necessarily follow. Importantly, an unremunerated CBDC with elastic supply would limit monetary policy space by introducing a hard zero lower bound on interest rates.³⁴

Instead, a remunerated CBDC could be an option to overcome the effective lower bound (ELB) on interest rates (Bordo and Levin 2017, Lilley and Rogoff 2020). The remuneration could be adjusted with policy rates over the business cycle and potentially become negative, thereby eliminating the potential for a liquidity trap. However, this would require phasing out banknotes to prevent cash hoarding when interest rates on digital currency become negative, which major central bank have already committed not to do (Group of Central Banks, 2020).³⁵

Bindseil (2020) notes that in a negative interest rate environment demand for CBDC would be potentially unlimited if it were remunerated at a zero interest rate. At the same time, a CBDC carrying a negative interest rate might face adoption obstacles as users would perceive cash as a less costly means of payment. To steer demand, Bindseil therefore proposes a tiered remuneration system, in which a first tier of CBDC holdings would be remunerated at a non-negative interest rate whereas a second tier would bear an unattractive penalty rate, and the remuneration on both tiers would potentially move in tandem with policy rates. Such a scheme, however, would be difficult to explain to the public and might impede adoption as well as usability of CBDC for the average consumer, in particular in the presence of alternative private digital means of payment. Moreover,

³³ Alternatively, banks could demand greater compensation for interest rate risk in the form of higher term premia.

³⁴ In contrast to banknotes, CBDC can be held at no cost and without risk of loss or theft, which would prevent central banks to lower policy rates into negative territory.

³⁵ Lilley and Rogoff (2020) list a number of other approaches to discourage cash hoarding in the presence of a negative remuneration on a digital currency, among others phasing out larger banknotes (Rogoff 2016) or creating a crawling peg between paper and electronic money (see also Agarwal and Kimball 2019, or Assenmacher and Krogstrup 2021).

CBDC holdings could be more responsive to changes in policy rates than cash and probably also than bank deposits that currently react to policy rate changes only partially and with a lag. This would potentially strengthen the transmission of policy rate changes to bank funding rates and might thereby also increase the transmission to bank lending rates (Whited et al., 2022).³⁶

Beyond strengthening monetary policy transmission, a remunerated CBDC could give the central bank an additional tool that it could use for targeting other objectives, such as the exchange rate or the liquidity premium on bank deposits. By operating as a means of exchange, CBDC opens up new channels for monetary policy to affect output and inflation. Assenmacher et al. (2022) link a New Monetarist model to a New Keynesian model with financial frictions and show that the central bank can separately target the store-of-value and the means-of-exchange function of money by steering the supply of CBDC. This offers an additional channel for stabilising the economy by exploiting a trade-off between payments efficiency, bank funding conditions and the opportunity cost of holding money. This is in line with Keister and Sanches (2022), who conclude that welfare is often maximised when the central bank uses the CBDC interest rate to increase total real money balances and lower the equilibrium liquidity premium, although this results in some bank disintermediation. George, Xi and Alba (2020) use a slightly different modelling setup in an international context and find that the existence of CBDC allows monetary policy to target both the domestic price level and the exchange rate, analogous to sterilised foreign exchange interventions.

The implications of CBDC for monetary policy implementation and transmission will largely depend on the characteristics of CBDC and the design choices that will be made. Amongst the key choices, central banks will need to decide who should be able to use CBDC, whether and how it would be remunerated, and whether its use would be subject to holding or transaction limits (Auer et al. 2020). As stated in the introduction, we abstract from wholesale considerations and only consider the implications of a retail CBDC accessible to citizens and firms. One question is whether the use should be confined to domestic users or whether also non-residents would be allowed to transact with a domestic CBDC. While CBDC could increase the efficiency of cross-border payments significantly, it could potentially lead to large cross-border financial flows and create new international arbitrage conditions between domestic and foreign interest rates and the exchange rate. Large holdings of a foreign CBDC could potentially lead to stronger international spillovers and complicate monetary policy trade-offs for economies not issuing a CBDC (Ferrari et al. 2022).

³⁶ See Jiang and Zhu (2021) for an analysis of the interactions between the potentially different interest rates on reserves and CBDC.

Remuneration has been identified as one important attribute that affects the potential demand for CBDC (see Li, 2021). While a tiered remuneration would allow a central bank to influence demand and use the CBDC rate as an additional policy tool, it is less clear whether changes in the remuneration would be sufficient to control demand also during crisis episodes. Fegatelli (2021) proposes to deal with large shifts in CBDC demand by using reserve requirements as a tool for macroeconomic stabilisation instead of only changing policy rates.

Alternatively, holding or transaction limits have been proposed as an additional safeguard to steer demand for CBDC (European Central Bank, 2020) and avoid CBDC crowding out bank deposits, thereby interfering with monetary policy transmission and financial stability objectives (see also Section 5.1). While holding limits would be highly effective in constraining the overall amount of CBDC in circulation, they come with certain drawbacks. First, it is difficult to calibrate a holding limit that can equally be applied to different users of CBDC, such as households and firms with potentially very different payment needs.³⁷ Second, constraining holdings to a maximum amount may give rise to a shadow price of CBDC compared to other forms of money. Third, as holding limits could constrain the ability of a payee to accept payment in CBDC, it might conflict with declaring CBDC legal tender. A possible solution could be to combine such limits with a waterfall approach that transfers amounts exceeding the maximum holding amount to a bank account (Bindseil et al. 2021). This, however, would make CBDC less financially inclusive as its use would be tied to the possession of a bank account. Finally, limits may give rise to commitment problems similar to the ones known from the optimal monetary policy literature (see e.g. Woodford 2003) as the central bank may find it difficult to enforce or tighten these limits when they are needed most (e.g. in the case of a bank run).

Overall, it can be concluded that although safeguards allow the central bank to better control the amount of CBDC in circulation, they also give rise to wedges that increase the liquidity premium on CBDC and therefore limit the associated welfare gains (Assenmacher et al. (2021), Keister and Sanches (2022), Burlon et al. (2022)).

This is illustrated in Figure 5, which is based on Assenmacher et al. (2021). As the interest rate spread between the central bank's lending rate for CBDC relative to the rate for holding CBDC increases, welfare is reduced (Panel A). Conversely, welfare increases when more collateral is available or when the central bank raises the maximum amount of CBDC that it is willing to issue (Panels B and C). The figure also demonstrates that the welfare effects depend on the degree of

³⁷ This problem remains even if holding limits could be differentiated for different users, as the limit would need to be based on an objective and easily observable statistics.

substitutability between CBDC and bank deposits. The higher the degree of substitution, the smaller is the welfare loss from restricting the availability of CBDC, suggesting that such tools are less costly if the risk of bank disintermediation is high.

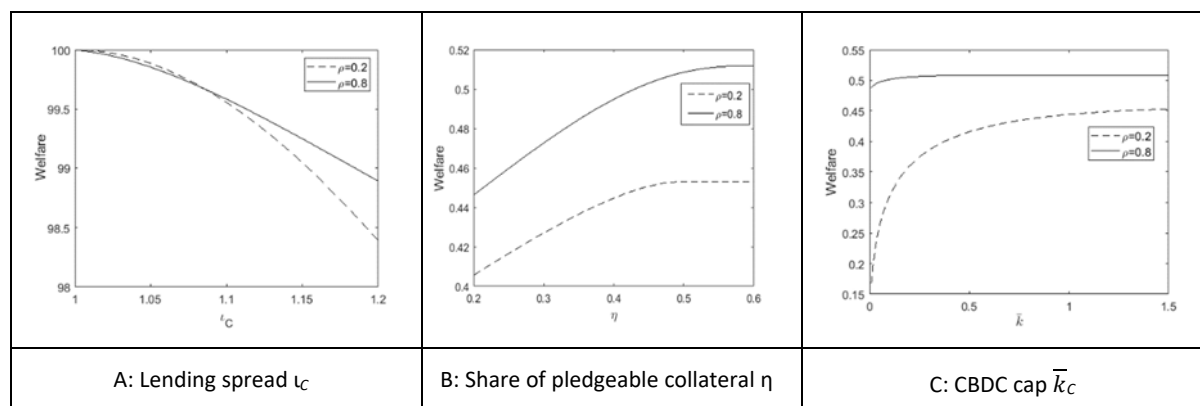


Figure 5. Welfare as a function of the lending spread, the share of pledgeable collateral and the CBDC cap for different degrees of substitutability ρ .

4.3 CBDC and implications for monetary policy implementation

A CBDC introduction will have implications for monetary policy operations as well as the size and structure of the central bank's balance sheet that depend, on the one hand, on the amount of CBDC that would be in circulation, and, on the other hand, on how the central bank reacts to this demand. Brunnermeier and Niepelt (2019) and Niepelt (2020a, 2020b) argue that the introduction of CBDC would be neutral with respect to bank funding if the central bank undoes the effects resulting from a substitution of deposits for CBDC by lending more to banks. Figure 6 depicts the resulting balance sheet adjustments. When a CBDC becomes available, households may decide to substitute some of their deposits for CBDC. If banks have sufficient reserves to accommodate the deposit outflow, their balance sheet size would decrease and reserves would be substituted for CBDC on the central bank's balance sheet (hatched red arrows in Figure 6). If banks' reserve holdings were insufficient, they would need to obtain additional reserves by borrowing from the central bank, which would imply a lengthening of the central bank's balance sheet (hatched green arrows in Figure 6).³⁸

³⁸ As an alternative to the usual liquidity-providing repo operations, the central bank could also decide to conduct outright purchases, i.e. acquiring securities from the banking sector.

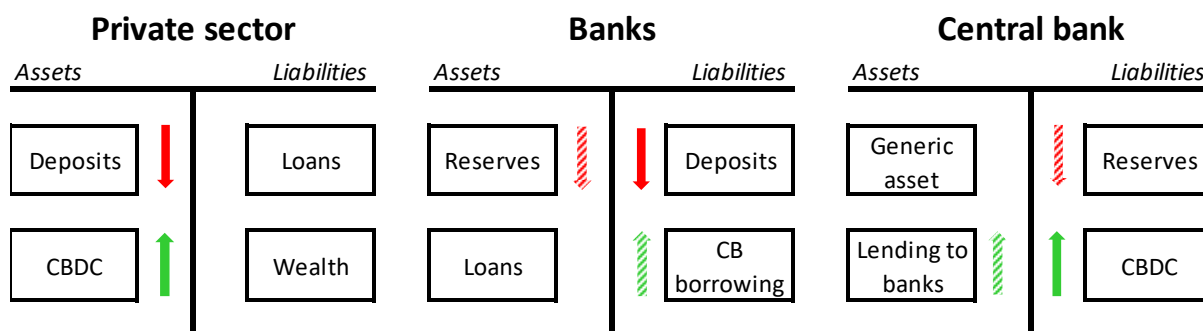


Figure 6. Stylised balance sheets of private sector, banks and the central bank upon introduction of a CBDC

To ensure that the capital allocation and prices are not affected by the introduction of CBDC, central bank loans to banks would have to replicate the characteristics of deposits lost by banks. In particular, they would have to be uncollateralised. As long as the central bank maintains its collateral standards, equivalence of CBDC and deposits can therefore not be ensured. Williamson (2022a) notes that the central bank may have to take on private assets in its portfolio if CBDC significantly displaces privately supplied means of payment. Fernández-Villaverde et al. (2021) argue that the equivalence result is fragile and will break down in an economy that is prone to financial crises because a central bank is more stable than commercial banks. As depositors would anticipate this, CBDC would crowd out deposits completely. Frascini et al. (2021) investigate the equivalence result with a particular focus on the efficiency in the provision of CBDC. If CBDC is provided more efficiently than bank deposits, the central bank's balance sheet and seigniorage revenues will increase, may allow for a reduction in taxes if the effect is quantitatively important.³⁹ Kahn et al. (2022) argue that, to the extent that a CBDC increases the usefulness of central bank money and draws demand away from private monetary assets, it has the potential to increase the central bank's control over monetary policy and its ability to reap seigniorage.

The impact of CBDC on monetary policy implementation depends on the size of CBDC demand and the policy environment at the time of the CBDC introduction. Volatility in the demand for CBDC could make interest rate control in a corridor system more challenging. This might be easier to handle in a floor system where excess reserves are sufficiently large (see Malloy et al., 2022). In this case, a CBDC introduction in an environment with large excess liquidity would allow banks to satisfy CBDC demand by running down their excess reserves. Whenever excess reserves face a negative interest rate, such a conversion could affect bank profitability positively, although it needs to be recognised that the distribution of excess reserves is not homogeneous across banks (Adalid et al. 2022, Fegatelli 2021).

³⁹ Note that the effect on seigniorage depends on the level of CBDC remuneration.

The emergence of new forms of digital money may also require the central bank to rethink its counterparty framework. If non-bank entities were to distribute CBDC to the public, they might require direct access to the central bank's balance sheet in order to manage CBDC distribution efficiently.⁴⁰ If a CBDC existed, private stablecoin issuers could also consider holding it as a part of their reserve (Libra Association, 2019).

In sum, a CBDC would require the central bank to rethink its monetary policy implementation framework. Besides the question how a potential CBDC remuneration would fit into the set of key policy rates, a sufficiently large CBDC take-up would have implications for the size and structure of the central bank's balance sheet that could impact the operational framework, i.e. corridor or floor, and the type and maturity of operations (refinancing operations versus outright purchases).

5 Implications for financial stability

Financial stability considerations feature prominently in the policy discussion on CBDC (see BIS, 2021b). The concerns primarily focus on the safety and remuneration of CBDC claims relative to bank deposits, and the resulting implications for bank stability.⁴¹

The financial stability implications of CBDC are likely to operate through several different channels. Ultimately, bank stability is the result of banks' and creditors' decisions, which are further intertwined with the effectiveness of prudential regulation and the LOLR policy in place. One way to illustrate this is to differentiate between the effects of CBDC on the liability and asset sides of the bank balance sheet. The former refers to the impact on funding costs and short-term liquidity through creditors' withdrawal decisions. The latter, instead, encompasses the implications for banks' risk-taking incentives. In addition, as we illustrate in detail below, separate considerations on the effect of CBDC on the ability of authorities to intervene and enhance stability are also relevant to financial stability.

5.1 The liability side: Fragility and (digital) bank runs

On the liability side, bank fragility is rooted in their role as liquidity providers (Diamond and Dybvig, 1983; Goldstein and Pauzner, 2005). Banks raise funds in the form of demandable deposits and invest them in illiquid and risky assets. While this structure enables them to provide liquidity insurance to

⁴⁰ Similarly, the central bank may also consider broadening its collateral framework.

⁴¹ Despite the presence of deposit insurance, a large fraction of bank deposits in the US and Europe are uninsured (see, e.g., Egan et al. 2017 for US data). Furthermore, the lack of a pan-European deposit insurance scheme has undermined the credibility and effectiveness of national deposit insurance schemes during the sovereign debt crisis. Accordingly, financial stability risks due to bank runs remain economically important.

risk-averse depositors, the resulting maturity mismatch exposes them to the risk that depositors withdraw their funds before the maturity of their assets (a “bank run”).

Bank runs occur either because i) depositors panic and withdraw early out of the self-fulfilling belief that other depositors will do the same and the bank will fail (Diamond and Dybvig, 1983) or ii) due to a deterioration of economic conditions (Gorton 1988, Allen and Gale, 1998, 2004). Irrespectively, depositors choose to withdraw early because they expect to receive a higher repayment from doing so. The value of the available outside investment opportunity when running is then crucial in determining depositors’ withdrawal incentives and, in turn, the probability of a bank run.

This logic captures policy makers’ concern that the introduction of a CBDC could lead to an increase in bank fragility (see, e.g., Broadbent, 2016; Callesen, 2017). Given its safety (plus the potential to carry interest), CBDC is considered to increase run incentives relative to an economy where cash holdings are the only alternative to bank deposits. This is especially true when depositors have low expectations about bank health because converting bank deposits into CBDC shields them from the risk associated with a bank failure. Since the central bank can always honor its debts by printing currency, it is perceived as a safe investment and not subject to runs. Consistent with this flight-to-safety view, Williamson (2022b) shows that the introduction of CBDC increases the set of parameters for which runs on bank deposits can occur in a multiple equilibrium model.

The above flight to safety argument hinges on the fact that CBDC holdings are shielded from runs. This point is explored in Skeie (2020), where CBDC eliminates the bank run problem: The central bank prints money and this implies that nominal deposit claims are always honoured, although the real value of these claims falls. This aspect is also present in Schilling et al. (2021), where the introduction of CBDC confronts the central bank with a trilemma between the central bank's traditional price stability objective, the attainment of the efficient allocation of resources and the maintenance of trust in the value of currency. However, their analysis does not feature commercial bank runs, since CBDC fully crowds out bank deposits (as in Fernández-Villaverde et al., 2021).

Allowing for runs on commercial banks, Ahnert et al. (2022) study the implications of CBDC remuneration for bank fragility. They model an economy in which investors can either hold their funds in bank deposits or in CBDC accounts with the central bank. In their global-games framework, the probability of a bank run is endogenous and depends on the level of CBDC remuneration and the terms of the deposit contract set by profit-maximizing banks. In this setting, a change in CBDC remuneration has two countervailing effects on the probability of a bank run. On the one hand, a higher CBDC remuneration increases the incentive for depositors to run into CBDC since it enables higher

consumption in the future. This mechanism is illustrated in Figure 7 (Panel A), which shows that, all else equal, an increase in the remuneration of CBDC leads to a higher probability of a bank run. On the other hand, an increase in CBDC remuneration induces banks to counter a potential outflow of deposits by adjusting the deposit contract. To compensate depositors for the more valuable outside option and the associated higher fragility, banks raise the promised repayment to depositors, as shown in Panel B of Figure 7. This, in turn, decreases the incentive to withdraw early and thus the probability of a bank run (Figure 7, Panel C).

Since the two effects described operate in different directions, the relationship between CBDC remuneration and bank stability need not be monotonic. In particular, if bank lending is sufficiently profitable, it will be U-shaped as illustrated in Panel D of Figure 7. In this case, some positive but not too high CBDC remuneration reduces financial fragility relative to an economy with only cash.

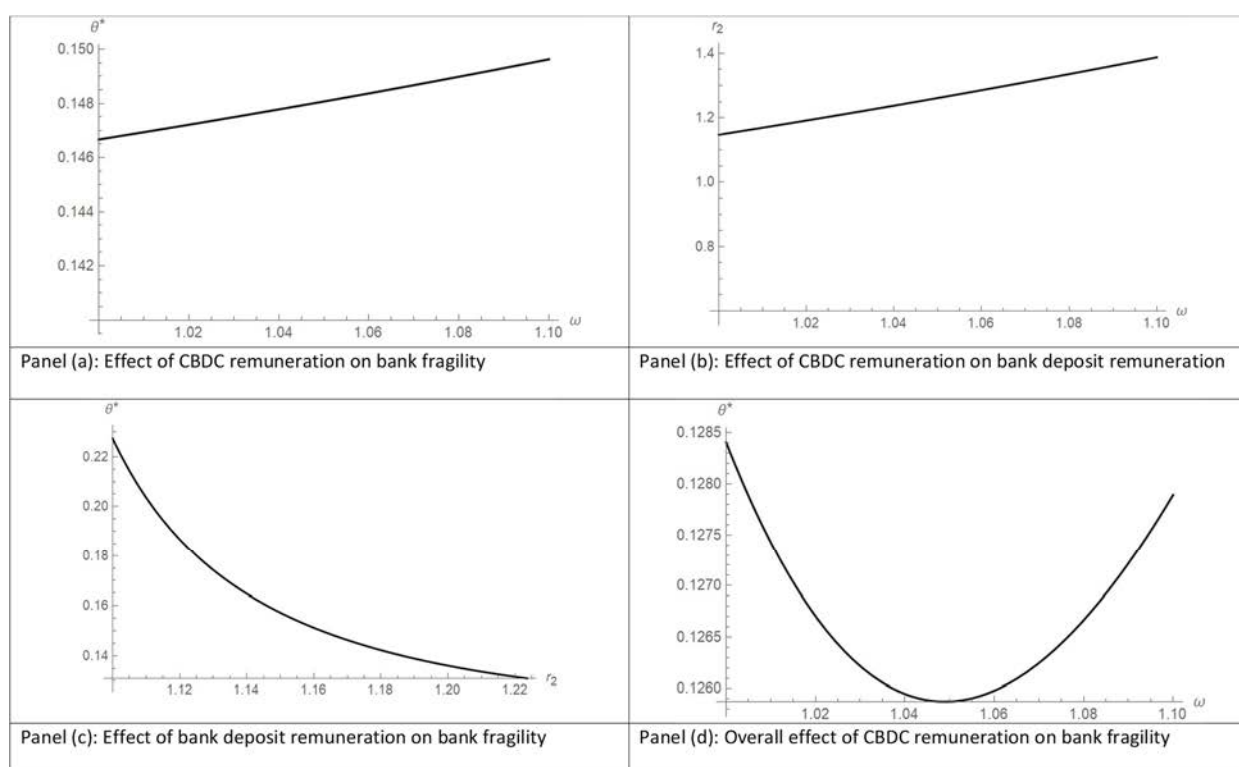


Figure 7: CBDC remuneration and bank fragility. Notes: The variable ω captures the gross CBDC remuneration, so the economy without CBDC corresponds to the case where $\omega = 1$. Financial fragility is measured by the variable θ^* , which represents the endogenous probability of a bank run. The remuneration of bank deposits is denoted by r_2 . The graphs are based on the following parameter values: Liquidation value $L=0.9$, date-2 project return $R=15$. Source: Ahnert et al. (2022).

The analysis above focuses on the effect that CBDC has on financial stability, through the impact it has on depositors' incentives to run. It abstracts from changes in the type of funding banks raise and in the amount of bank deposits, both of which may have implications for financial stability. However, the

introduction of CBDC may also have an impact on both the costs of retail deposits and their quantity. As retail deposits become more expensive following the introduction of CBDC, banks may have incentives to substitute retail deposits with less stable, but cheaper, sources of funding, like wholesale deposits, thus increasing bank fragility.⁴² Similarly, by representing a safe and valuable investment opportunity, the introduction of CBDC may induce investors to substitute bank deposits with CBDC accounts. This reduction in bank deposits can also have negative implications for financial stability: as the supply of private credit is reduced, the nominal interest rate rises and banking panics can occur for a larger set of parameters (Kim and Kwon, 2022).

The potential negative consequences for financial stability associated with the introduction of CBDC can be curbed by design features such as CBDC remuneration or holding limits (see the discussion in Section 4.2). Holding limits aim at preventing that CBDC crowds out bank deposits, although they do not curb depositors' incentives to run into CBDC, especially when there are concerns about banks' health. Similarly, a recalibration of liquidity requirements for banks to account for the higher risk of deposit outflow could be implemented to reduce the consequences of runs into CBDC. A remuneration of CBDC below short-term market rates has been proposed as a way to limit the attractiveness of CBDC relative to bank deposits to minimize both the risk of a run and bank disintermediation. In the context of the Eurosystem's digital euro project, pros and cons of introducing a quantitative cap on digital euro holdings or a tiered remuneration are investigated (Panetta, 2022).

5.2 The asset side: profits margin and risk-taking incentives

On the asset side of their balance sheet, banks' risk-taking decisions are a key driver of fragility. Traditionally, changes in risk-taking incentives have been associated with changes in profit margins. Since lowering risk on the asset side entails costly screening and monitoring, banks are only willing to exercise such effort if they expect to accrue sufficiently large gains in return. This is the reason why increased risk-taking has been traditionally linked to more competitive banking markets, (Keeley, 1990) or accommodative monetary policy (Dell' Ariccia, Laeven and Marquez, 2014; Repullo and Martinez-Miera, 2017 and Heider and Leonello, 2021).

Building on these arguments, a CBDC introduction may lead to increased risk-taking due to reduced bank profitability and compressed interest margins. This may operate through different channels. First, as discussed in the previous section, banks may respond to the introduction of CBDC by increasing deposit rates. Unless they are able to compensate this increase in funding costs through higher lending rates, interest margins will decline and give rise to excessive risk-taking and financial

⁴² Evidence of a similar substitution between (stable) retail and (unstable) wholesale deposits following a monetary policy tightening is provided in Choi and Choi (2021).

instability. Second, even if banks can pass on the increase in funding costs to borrowers, they are likely to face a reduction in lending volumes. However, Monnet et al. (2021) challenge this view. In their model, an increase in the interest paid on CBDC lowers the real price of capital. This allows banks to lend more, and to increase their profits despite the associated increase in funding costs. As a result, the incentives to engage in risk-taking decline.

CBDC may also affect banks' risk-taking incentives by affecting market discipline. This argument closely relates to the impact of CBDC on depositors' withdrawal incentives, since the probability of a run determines banks' expected profits and also captures the extent of discipline that depositors exercise on banks (Calomiris and Kahn, 1991). Thus, changes in the threat of a run triggered by the introduction of CBDC also affects banks' incentives to take risk. Two mechanisms are at play. On the one hand, a stronger threat of a run translates into more discipline for banks. Banks anticipate that depositors are ready to react to their risk choices and so, in the attempt to avoid the losses associated with early liquidation, banks take less risk. On the other hand, when the run probability is high, banks are confronted with lower expected profits, thus reducing their incentives to behave prudently. Whether CBDC fosters banks' risk-taking incentives, then, depends on how it affects runs, as well as on the impact of a change in the run probability on banks' profits.

5.3 Impact on financial stabilization policies

Thus far, our discussion has abstracted from the role played by prudential policies and interventions (bailouts, deposit insurance, lender-of-last-resort support) for curbing distorted incentives and enhancing financial stability. Their design is crucial for their effectiveness, as well as for minimizing the potential side effects in terms of moral hazard (Keister, 2016; Allen et al. 2018; Gale and Vives 2002). Crucial features include the timing of the intervention, the information the policy authority has on banks' health and the fundamentals of the economy, and its commitment to a specific size and type of intervention.

Given their role in enhancing financial stability, it is important to understand whether and how the introduction of CBDC may interact with prudential policies. In particular, can CBDC help prudential authorities in supporting financial stability? If so, which design features of CBDC may play an important role?

Keister and Monnet (2022) study the role of CBDC on policy interventions by a public authority which lacks commitment and learns the state of the economy with a lag. In their framework, the following trade-off is at play. On the one hand, a CBDC leads to more runs because it provides a more profitable outside option to bank depositors. On the other hand, a CBDC enables the policy maker to acquire real-time information on banks' health by monitoring the flow of resources in and out the CBDC

accounts. This allows for more timely interventions. Depending on which of these two effects dominates, the introduction of CBDC may decrease or increase financial stability. The analysis also speaks to the debate on design features. From a financial stability perspective, an account-based CBDB would be preferable to a token-based system where such information is impossible to obtain. Furthermore, the introduction of limits would reduce the precision of the information that can be obtained by the public authority.

Finally, the introduction of CBDC can also improve financial stability by reducing the moral hazard problem associated with implicit support guarantees for the banking sector. Part of the rationale for support from policymakers is banks' essential role in the payment system. With the introduction of CBDC, banks become less special, which reduces the social case for preferential treatment and, the associated distortions.

6 Policy issues and challenges

This section discusses a number of issues and challenges that are of first-order significance in the policy debate on CBDC. First, we discuss potential alternatives for reaching some of the objectives that CBDCs aim to achieve. We then discuss issues related to end-user adoption, followed by political economy considerations.

6.1 Regulatory alternatives

While many central banks are actively engaged in researching the potential of CBDCs, they have thus far only been launched in two countries, namely the Bahamas (Sand Dollar) and Nigeria (e-Naira). At the same time, some prominent policy makers have voiced concerns that CBDC is “a solution in search for a problem”.⁴³ While survey data shows that central bankers view a CBDC introduction as an increasingly realistic scenario (Kosse and Mattei, 2022), it is natural to ask whether some of the key objectives (outlined in Section 3) could be reached through alternative approaches.

There is no regulatory alternative that promises to eliminate the threat to the two-layer monetary system. Since cash is only available in physical form, it is by construction not “fit” for the digital age. Regulations that aim at maintaining its large-scale use are likely to imply large economic costs without clear benefits. Accordingly, the introduction of digital cash in the form of a CBDC appears to be the only solution to guarantee a smooth continuation of the current monetary system.

⁴³ See <https://www.federalreserve.gov/newsevents/speech/waller20210805a.htm> and <https://www.fn london.com/articles/ex-boe-governor-mervyn-king-calls-bitcoin-a-solution-without-a-problem-20220118>.

The threat to monetary sovereignty is a major one. The explosive mix of BigTech and cryptocurrencies – especially stablecoins – is at the center of attention, and the strength of network externalities in payments and digital services implies that public policy must act decisively and in a forward-looking manner. Absent regulatory action, stablecoins are subject to the same financial stability risks as other forms of weakly regulated private money, such as banknotes during the “free-banking era” or money-market mutual funds before the 2007-08 financial crisis (Kacperczyk and Schnabl, 2013; Gorton and Zhang 2021). These concerns became very tangible in May 2022, when the then fifth-largest stablecoin Terra was wiped out in a matter of days following a crash in its major reserve asset, the cryptocurrency Luna.⁴⁴ Concerns about the quality of the reserve asset pool also induced a significant temporary price drop in Tether, the world’s largest stablecoin (see Figure 8).⁴⁵

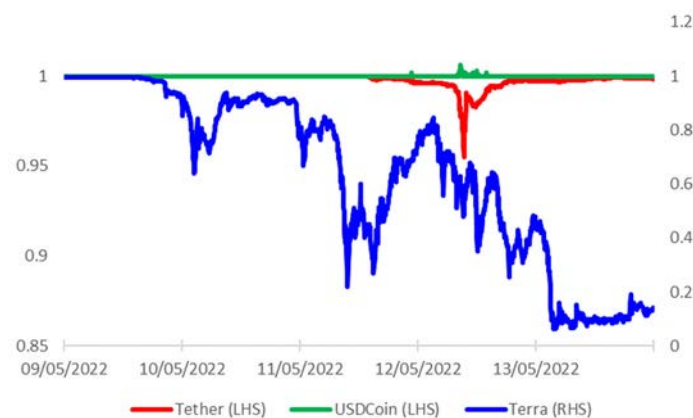


Figure 8. This figure depicts the price evolution (in USD) of three major stablecoins (Tether, USDCoin, and Terra) from May 9th to May 13th, 2022. Source: Refinitiv.

At the same time, our current monetary system is the result of carefully designed regulation. It is therefore not obvious that adjustments to the regulatory framework are not a viable alternative to a CBDC. Lawmakers in advanced economies are currently drawing up regulatory proposals to this end. For example, the EU Markets in Crypto-Assets Regulation (MICA) aims to restrict the issuance of stablecoins to banks and so-called e-money institutions.⁴⁶ In the United States, the President’s

⁴⁴ Notably, Terra was a so-called algorithmic stablecoin, which typically rely on hard-wired exchange rate policies implemented through smart contracting on a blockchain. In principle, such arrangements have the potential to solve commitment problems (see Routledge and Zetlin-Jones, 2021). However, in this case the value of the backing collateral became essentially worthless, which rendered the mechanism ineffective and exposed the design flaws in Terra.

⁴⁵ In an interview held during the same week, Tether’s chief technology officer declined to provide detailed information about the collateral pool. See Financial Times, “Crypto industry shaken as Tether’s dollar peg snaps”, May 12, 2022.

⁴⁶ Broadly speaking, e-money institutions are payment providers without a banking license. They face capital requirements, are subject to supervision, and typically are required to hold customer funds in the form of

Working Group has published a report that recommends even tighter rules, including limits on the affiliation with commercial entities (such as “BigTech”). In the meantime, at least one major stablecoin issuer (Circle/USDCoin) has announced plans for obtaining a US banking license.⁴⁷

These proposals would bring new forms of digital money into the regulatory perimeter and help to address some of the major concerns related to monetary sovereignty and financial stability. Moreover, strict limitations on the universe of eligible reserve assets (e.g. short-dated government bonds) could curb incentives for risk-taking.⁴⁸ However, Gorton and Zhang (2022) point out that stablecoins constitute “circulating money” (i.e. token-based money) and argue that protecting them through the public safety net – especially deposit insurance – may be infeasible because it only applies to account-based money (at least in its current form). Accordingly, they advocate to strengthen the public monopoly on circulating currency.

Some of the issues related to privacy in electronic payments could be addressed by expanding upon existing regulatory frameworks, such as the General Data Protection Regulation (GDPR) and the Revised Payment Services Directive (PSD2) in the European Union. However, the proliferation of data does not only create privacy concerns, but also promises significant efficiency gains. Accordingly, a blanket prohibition of the use of payments data are unlikely to be a socially optimal solution. At the same time, disparities between public and private values of privacy (Garratt and van Oordt, 2021) and the “privacy paradox” imply that market forces alone will not lead to desirable outcomes in terms of data sharing, so that regulatory intervention may be required.

Finally, central bankers expect CBDCs to increase the efficiency of payment systems (Boar and Wehrli, 2021). The key question is whether upgrades of the current infrastructure towards “fast payment systems” could attain similar benefits without making major changes to the overall financial system. This is of particular relevance for the euro area, where payment systems remain fragmented along national borders, so that progress towards a better infrastructure has progressed in an uneven manner.⁴⁹ The European Payment Initiative (EPI) is a private-sector attempt to build a

commercial bank deposits (which may or may not enjoy the benefits of pass-through deposit insurance, depending on the regulatory framework).

⁴⁷ See <https://www.forbes.com/sites/stevenehrlich/2022/04/05/ceo-behind-50-billion-stablecoin-explains-why-not-all-digital-dollars-are-created-equal/?sh=198ca7f67972>

⁴⁸ In the extreme, regulators could even require stablecoins to be backed one-for-one with central bank reserves. Such “synthetic CBDC” (Adrian and Mancini-Griffoli, 2021) arrangements would provide the broader public with indirect access to central bank money, even though they represent private sector liabilities. At the same time, they would broadly lead to the same concerns regarding bank disintermediation and financial stability as a fully-fledged CBDC.

⁴⁹ Examples for successful transitions to more efficient payments systems, including P2P transfers, include Swish in Sweden and Bizum in Spain.

pan-European retail payment system in order to increase efficiency and lower the dependence on large non-European providers such as VISA, Mastercard and Paypal. However, progress has stalled and a significant number of banks have left the consortium in the meantime in order to retain focus on existing national solutions, citing a lack of public financial backing in the light of significant set-up costs.⁵⁰ Similarly, the Eurosystem's instant payments services TIPS has not led to a proliferation of fast retail payments. Brazil's successful launch of "Pix" suggests that regulatory intervention may be a powerful tool in establishing the sufficient network effects required for widespread adoption of such services (Duarte et al., 2022).

6.2 Too much vs. too little - ensuring adoption of CBDC

Much of our discussion has highlighted the risk of "excessive" CBDC take-up and the resulting implications for monetary policy and financial stability. At the same time, central banks will also be keen to avoid introducing a product that is not used in practice. While some theoretical models stress the value of CBDC as "outside option" for disciplining private actors, a low take-up would likely signal low user demand, and at least lead to a public perception of "failure". Moreover, a lack of adoption may also diminish the ability of CBDC to act as a public anchor for the monetary system. Accordingly, it is important to understand the determinants of users' choices in the market for payments.

Due to the existence of strong network externalities, the barriers to entry in the market for payments are extremely high. To be successful, a new means of payment must attract a critical mass of both merchants and consumers simultaneously. Consistent with the asymmetric pricing structure predicted by theoretical models, merchants typically face relatively high interchange fees.⁵¹ Accordingly, a CBDC based on cost-recovery could aim at ensuring widespread adoption by merchants, which would be a necessary condition for becoming a successful means of payment. It would also be consistent with previous efforts to regulate interchange fees as a tool to increase merchant acceptance (Valverde et al, 2016).⁵² However, as digital payments can be bundled with other services such as data analytics (e.g. Paypal Marketing Solutions) or consumer credit (e.g. Klarna, Affirm), merchant adoption may no longer be exclusively driven by cost considerations.

⁵⁰ See "New European payments project hits major snag", Reuters, December 23, 2021.

⁵¹ Interchange fees refer to the payment that the merchant's bank makes to the consumer's bank whenever a purchase is settled using a card, both debit and credit. These fees are then transferred by the merchant's bank to the retailer, which, in turn, may pass the fees on to consumers by charging higher prices.

⁵² In the European Union, interchange fees are regulated under EU Directive 2015/2366. They are currently capped to 0.2/0.3% of the transaction value for consumer debit/credit cards.

Accordingly, a successful CBDC must be embedded into an infrastructure that facilitates such bundling since it otherwise risks being supplanted by private payment solutions.

Success, however, also requires uptake by the consumer. There is an extensive empirical literature analysing the determinants of payment choices in retail markets. Most studies find that consumers tend to make small payments in cash and resort to electronic payments such as debit and credit cards for larger amounts (Klee, 2008; Chen et al., 2021). This behaviour is consistent with the classical Baumol-Tobin view of opportunity costs (in terms of foregone interest) as key determinant for money demand (Baumol, 1952; Tobin, 1956, Alvarez and Lippi, 2009). This is also supported by Li (2021), who predicts that a 0.1% increase in CBDC remuneration would increase demand by 8% to 18%. More broadly, the empirical evidence suggests that consumers act cost-consciously: they avoid payment methods that incur additional fees and indulge those that grant rebates such as bonus points (Ching and Hayashi, 2010; Carbó-Valverde and Liñares-Zegarra; 2011, Simon et al., 2010).

The secular shift from cash to electronic payments has also revealed a non-trivial role of non-monetary factors such as convenience and transaction speed. While card payments used to be relatively cumbersome and slow (Klee, 2008), innovations such as contactless payments are tilting the balance away from cash even for smaller amounts (Brown et al, 2021). Moreover, consumers tend to develop habits in their payment behaviour: Once they settle for a preferred payment method, they exhibit a significant aversion to adopting other alternatives (Van der Cruysen et al, 2017; Berg et al., 2019). In a recent study commissioned by the ECB, consumers express a strong preference for seamless one-stop solutions that avoid the inconvenience associated with multi-homing, such as having to deal with different cards/devices (Kantar Public, 2022).

Privacy is a central aspect of the debate on digital money. Die-hard fans of cryptocurrencies view the ability to transact in full anonymity in the digital world as key feature.⁵³ In the context of digital retail payments, survey evidence suggests that consumers are aware of privacy issues, but do not consider them as primary concerns (Kantar Public, 2022). While Li (2021) finds that reduced levels of anonymity would lead to a decline in the demand for CBDC, her estimates are based on survey data and thus subject to the “privacy paradox”, which has also been documented in the context of digital payments (Chen et al., 2021). Accordingly, modest monetary incentives may be sufficient to compensate consumers for the reduced levels of privacy of private payment solutions, at the expense of depressed CBDC demand. This is a source of concern, since the wedge between the

⁵³ Another feature highlighted by proponents of cryptocurrencies is the ability to escape “excessive” government control, especially in the case of authoritarian regimes and economies with strong capital controls.

public and private values of privacy (Garratt and van Oordt, 2021) may entail a social welfare loss that can only be avoided through additional regulation of rebate schemes. Moreover, as shown in Ahnert, Hoffmann, and Monnet (2022), user preferences in terms of privacy may differ depending on the particular environment. This is also corroborated in recent survey evidence from Kantar Public (2022). Accordingly, a fixed privacy regime may jeopardize CBDC adoption.

Finally, little is known about the value that users attach to the bundling of payments and other services. Traditionally, money is both a means of payment and a store of value. However, current CBDC design proposals aim to separate these functions through the introduction of holding limits or tiered remuneration (Bindseil et al., 2021). While such restrictions may be successful at preventing potential adverse effects on bank lending and financial stability, their implications for user demand are not well understood. However, the success of large digital players in bundling payments with digital services suggests that these effects may be economically significant (Brunnermeier et al., 2019). It therefore appears crucial that a successful CBDC is built on an architecture that allows for the seamless bundling with financial and non-financial services.

In summary, a successful CBDC introduction requires central banks to strike the right balance. While “too much” adoption may have adverse effects on credit supply and financial stability, “too little” adoption also poses a significant risk. The market for payment services has changed considerably in recent years, as cash has become increasingly supplanted by electronic payments. Accordingly, additional research could shed light on how features such as bundling and privacy affect the choices of both merchants and consumers, and thus help policy makers in “getting it right”.

6.3 Political economy considerations

Issuance of CBDC exposes the central bank to operational risks, which may damage the central bank’s reputation. These are highly impactful risks since the central bank’s reputation with the public is key to successfully achieving its primary objective of price stability.⁵⁴ The largest of these operational risks is represented by cybersecurity. Kahn et al. (2021) point out that a tension exists between convenience and security of digital currencies, and report that theft of private digital currencies is quite common.⁵⁵ More generally, with the central bank taking direct responsibility for a larger payment system, also regular disservices and malfunctions, for which intermediaries are currently held accountable, may be

⁵⁴ With survey data, Christelis et al. (2020) find that higher trust in the ECB moves inflation expectations closer to the central bank’s inflation target. Ehrmann et al. (2013) show that unfavourable macroeconomic and financial developments are reflected in reductions in the public’s trust in the ECB.

⁵⁵ Aldasoro et al. (2022) also find that cryptocurrencies are particularly vulnerable to cyber-attacks.

pinned on to the central bank, reducing trust in the institution. Operational risks can be mitigated by giving a large role to intermediaries in the handling and onboarding of customers.

Currently, the interest rates set by the central bank affect households only indirectly, which may imply limited public attention to monetary policy. Introducing a remunerated CBDC with direct interest payments to retail depositors may make monetary policy measures more tangible for households. A seminal paper by Rogoff (1985) finds that, if central banks come under increased political pressure and adopt the preferences of the general public, they implement policies that lead to excessive inflation. This theoretical argument is the foundation for central bank independence. Goncharov et al. (forthcoming) find evidence consistent with this conflict between the public and the central bank. In light of this literature, greater political pressure may reduce central banks' ability to stabilize the economy. Moreover, since all households are net creditors in their CBDC balance, political pressure may not only become stronger but also more skewed towards advocating higher rates of interest. The resulting resistance to interest-rate cuts would be an additional constraint on monetary policy, potentially leading to suboptimal outcomes.

Fernández-Villaverde et al. (2021) caution that a successful introduction of CBDC would lead to a large flow of resources to the central bank and thereby empower political decision-makers to pursue wasteful policies. According to the paper, the advantages enjoyed by CBDC over bank deposits in terms of safety could give the central bank a position of monopoly in the market for deposits and therefore considerably increase its economic power. Conceivably, political pressure could leverage this economic power to pursue ends that are socially wasteful, such as subsidies for borrowing by well-connected firms. However, two considerations assuage this concern. First, it is unlikely that CBDC will completely take over the market for deposits as discussed in Section 4.1. Banks are likely to react to CBDC introduction by offering better conditions to depositors in order to retain market share. Second, central banks such as the ECB are independent exactly to avoid their economic heft being misused. Indeed, the opposite argument can be made: should the central bank come to enjoy monopoly rents, it may well end up deploying them in a socially beneficial manner. It could invest them in public goods, such as a resilient payment system.

7 Conclusion

The debate on the merits and drawbacks of CBDC is moving rapidly. While some aspects are well understood, the implications for monetary policy and financial stability often depend on the economic environment and specific design features. Moreover, several issues merit further analysis to improve our understanding of policy makers' options going forward.

Several conclusions emerge from our review of the literature. First, owing to the digital nature of CBDC and resulting accumulation of payment data, privacy is a complex issue that needs to be addressed. Externalities and private sector profit motives suggest that the public sector has a comparative advantage at the provision of privacy in payments. However, a one-size-fits-all solution with fully anonymity (KYC/AML issues aside) need not be optimal because users can also derive benefits from data-sharing.

Second, the literature suggests that policy makers' concerns about a contraction of credit supply following a CBDC introduction need not materialize when banks are able to exert market power in retail deposit markets. Issuing CBDC in such a situation would improve competition and increase welfare. Moreover, central banks could in principle cover the funding gap that would arise from a large-scale substitution of bank deposits into CBDC. However, frictions in current operational frameworks such as collateral requirements may impose limits on banks' recourse to the central bank.

Third, theoretical models suggest that the financial stability implications may be less severe than what conventional wisdom dictates. While the emergence of an attractive storage technology increases the risk of bank runs, banks will react and offer more attractive deposit contracts, which can alleviate, or even overturn, adverse effects on bank fragility.

Finally, central banks face a tension between too much and too little adoption. While safeguards such as holding limits or tiered remuneration have the potential to avoid excessive use and reduce the risk of disintermediation, it is important to understand their effects on user adoption. More generally, the rapid rise in electronic payments implies that user preferences are shifting rapidly as new means of payment are becoming available. However, relatively little is known regarding the value end-users attribute to certain features, including privacy and the convenience from bundling payments with other services.

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Appendix: CBDC remuneration and bank fragility

This appendix sketches the model of Ahnert et al. (2022) used in the main text to analyse how CBDC remuneration affects financial stability, particularly bank fragility. The economy extends over three dates $t=0,1,2$ and is populated by a bank and a unit continuum of investors $i \in [0,1]$. There is a single divisible good for consumption and investment. All agents are risk-neutral and do not discount the future. Investors are endowed with one unit of funds at date 0 only.

At date 0, the bank has access to a profitable but risky investment technology. The bank raises funds from investors in exchange for a demandable-deposit contract. Investment returns $L \in (0,1)$ if liquidated at date 1 (the liquidation value) and $R\theta$ upon maturity at date 2, where $\theta \sim U [0,1]$ is uniformly distributed and represents the fundamentals of the economy, and R represents the return from lending (or from financial intermediation more broadly).

The deposit contract specifies a repayment $r_1 \geq 1$ at date 1 and r_2 at date 2. It gives investors the option to withdraw before the maturity of investment. This decision is based on a noisy private signal about the fundamental at date 1:

$$s_i = \theta + \epsilon_i,$$

with $\epsilon_i \sim U [-\epsilon, \epsilon]$. The signal provides investors with information about the fundamental θ as well as the signals (and withdrawal actions) of other investors. We assume vanishing noise, $\epsilon \rightarrow 0$, which simplifies the analysis of date 0 choices and CBDC. As an alternative to bank deposits, investors can place their funds in a CBDC account both at date 0 and 1. The CBDC account is a direct liability of the central bank and pays a per-period interest $\omega \geq 1$.

The bank satisfies interim withdrawals by liquidating investment. When the liquidation proceeds at date 1 are insufficient to meet withdrawals, the bank is bankrupt due to illiquidity. Otherwise, the bank continues until date 2. If it cannot meet the remaining withdrawals at date 2, it is bankrupt due to insolvency. Bankruptcy is costly and we assume zero recovery.

The model is solved with standard global-games methods. That is, first, the withdrawal incentives of investors are determined, building on the methods of Goldstein and Pauzner (2005) and Carletti et al. (2022). Second, we solve for the bank's choice of deposit contract, especially the long-term deposit rate, and finally describe how both choices depend on CBDC remuneration. Using a numerical example, we obtain the charts reported in Figure 7 of the main text. They are drawn for parameter values $R=15$ and $L=0.9$. In Panel A, $r_2=2$, while CBDC remuneration $\omega=1.05$ in Panel B.

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