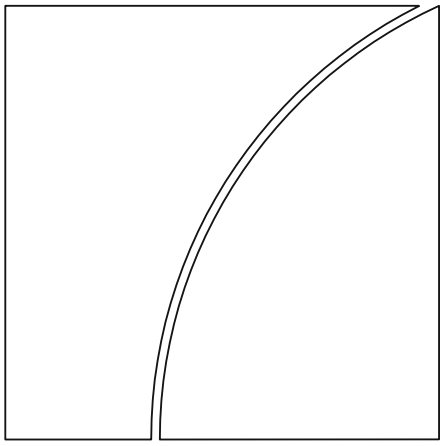
Committee on Payments and Market Infrastructures

Markets Committee



Central bank digital currencies

March 2018



BANK FOR INTERNATIONAL SETTLEMENTS

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Foreword

The history of central banking began with payment services. Since then payment-related innovation has always been an integral part of central banking. Modern examples include the establishment of systems allowing for immediate interbank gross settlement and the recent increased emphasis on faster retail payment systems. Central bank digital currencies (CBDCs) represent another such potential innovation. This joint report by the Committee on Payments and Market Infrastructures and the Markets Committee provides an initial analysis of CBDCs. It offers a high-level overview of their implications for payments, monetary policy and financial stability. The analysis of the committees reflects initial thinking in this rapidly evolving area and is a starting point for further discussion and research. It also highlights that the issuance of a CBDC requires careful consideration.

The Committees thank Klaus Löber (European Central Bank) and Aerdt Houben (Netherlands Bank) and the two Committee working groups for their efforts in preparing this report.

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Executive summary

Interest in central bank digital currencies (CBDCs) has risen in recent years. The Committee on Payments and Market Infrastructures and the Markets Committee recently completed work on CBDCs, analysing their potential implications for payment systems, monetary policy implementation and transmission as well as for the structure and stability of the financial system.

Key highlights of the work are:

- CBDC is potentially a new form of digital central bank money that can be distinguished from reserves or settlement balances held by commercial banks at central banks. There are various design choices for a CBDC, including: *access* (widely vs restricted); degree of *anonymity* (ranging from complete to none); operational *availability* (ranging from current opening hours to 24 hours a day and seven days a week); and *interest bearing characteristics* (yes or no).
- Many forms of CBDC are possible, with different implications for payment systems, monetary policy transmission as well as the structure and stability of the financial system. Two main CBDC variants are analysed in this report: a wholesale and a general purpose one. The wholesale variant would limit access to a predefined group of users, while the general purpose one would be widely accessible.
- CBDC raises old questions about the role of central bank money, the scope of direct access to central bank liabilities and the structure of financial intermediation. Traditionally, central banks have, for various reasons, tended to limit access to (digital) account-based forms of central bank money to banks and, in some instances, to certain other financial or public institutions. By contrast, physical central bank money, ie cash, is widely accessible. This approach has, in general, served the public and the financial system well, setting a high bar for changing the current monetary and financial structure.
- Wholesale CBDCs, combined with the use of distributed ledger technology, may enhance settlement efficiency for transactions involving securities and derivatives. Currently proposed implementations for wholesale payments – designed to comply with existing central bank system requirements relating to capacity, efficiency and robustness – look broadly similar to, and not clearly superior to, existing infrastructures. While future proofs of concept may rely on different system designs, more experimentation and experience would be required before central banks can usefully and safely implement new technologies supporting a wholesale CBDC variant.
- In part because cash is rapidly disappearing in their jurisdiction, some central banks are analysing a CBDC that could be made widely available to the general public and serve as an alternative safe, robust and convenient payment instrument. In circumstances where the traditional approach to the provision of central bank money – in physical form to the general public and in digital form to banks – was altered by the disappearance of cash, the provision of CBDC could bring substantial benefits. However, analysing whether these goals could also be achieved by other means is advisable, as CBDCs raise important questions and challenges that would need to be addressed. Most importantly, while situations differ, the benefits of a widely accessible CBDC may be limited if fast (even instant) and efficient private retail payment products are already in place or in development.
- Although a general purpose CBDC might be an alternative to cash in some situations, a central bank introducing such a CBDC would have to ensure the fulfilment of anti-money laundering and counter terrorism financing (AML/CFT) requirements, as well as satisfy the public policy requirements of other supervisory and tax regimes. Furthermore, in some jurisdictions central banks may lack the legal authority to issue a CBDC, and ensuring the robust design and operation of such a system could prove to be challenging. An anonymous general purpose CBDC would raise further concerns and challenges. Although it is unlikely that such a CBDC would be considered, it would not necessarily be limited to retail payments and it could become widely used globally, including for illegal transactions. That said, compared with the current situation, a non-anonymous CBDC could allow for digital records and traces, which could improve the application of rules aimed at AML/CFT.

- Issuance of a CBDC would probably not alter the basic mechanics of monetary policy implementation, including central banks' use of open market operations. CBDC introduces a new type of central bank money whose demand – like cash – would need to be accommodated. CBDC would also not necessarily affect the discretion that central banks have in choosing their monetary policy implementation techniques (eg reliance on purchases of securities or credit operations with banks) as well as the maturity, liquidity and credit risk of their assets. However, if flows into CBDC were to become large and not associated with offsetting declines in physical banknotes, as could be the case in times of financial stress, challenges could arise (such as a need to broaden the assets that the central bank can hold or take on as collateral).
- CBDC could enrich the options offered by the central bank's monetary policy toolkit, eg by allowing for a strengthening of pass-through of policy rate changes to other interest rates or addressing the zero lower bound (or the even lower, effective bound) on interest rates. It is not clear, however, that the current pass-through is anything but adequate. Furthermore, other more conventional tools and policies can to some extent achieve similar outcomes without introducing new risks and challenges (such as implementing negative interest rates on public holdings of a general purpose CBDC). And some of these gains might not arise without discontinuing higher denomination banknotes, which – although helping with AML/CFT requirements – would by itself entail some costs.
- Implications are more pronounced for monetary policy transmission and financial markets, especially if a CBDC was to be designed as, or de facto became, an attractive asset. As a liquid and creditworthy asset, a wholesale variant available to institutional investors that would be akin to interest-bearing central bank reserves or reverse repo facilities, yet widely tradeable, could function as a safe asset comparable in nature to short maturity government bills. A general purpose variant could compete with guaranteed bank deposits, with implications for the pricing and composition of banks' funding.
- The introduction of a CBDC would raise fundamental issues that go far beyond payment systems and monetary policy transmission and implementation. A general purpose CBDC could give rise to higher instability of commercial bank deposit funding. Even if designed primarily with payment purposes in mind, in periods of stress a flight towards the central bank may occur on a fast and large scale, challenging commercial banks and the central bank to manage such situations. Introducing a CBDC could result in a wider presence of central banks in financial systems. This, in turn, could mean a greater role for central banks in allocating economic resources, which could entail overall economic losses should such entities be less efficient than the private sector in allocating resources. It could move central banks into uncharted territory and could also lead to greater political interference.
- For currencies that are widely used in cross-border transactions, all the considerations outlined above would apply with added force, especially during times of generalised flight to safety. The introduction of a CBDC in one jurisdiction could adversely affect others. Central banks that have introduced or are seeking to introduce a CBDC should consider cross-border issues where relevant.
- Any steps towards the possible launch of a CBDC should be subject to careful and thorough consideration. Further research on the possible effects on interest rates, the structure of intermediation, financial stability and financial supervision is warranted. The effects on movements in exchange rates and other asset prices remain largely unknown and also deserve further exploration.
- More generally, central banks and other authorities should continue their broad monitoring of digital innovations, keep reviewing how their own operations could be affected and continue to engage with each other closely. This includes monitoring the emergence of private digital tokens that are neither the liability of any individual or institution nor backed by any authority. At this time, the general judgment is that their volatile valuations, and inadequate investor and consumer protection, make them unsafe to rely on as a common means of payment, a stable store of value or a unit of account.

1. Introduction

Some central banks have started to consider whether they might, at some stage in the future, issue digital currencies of their own. While providing greater access to digital forms of central bank liabilities is not an entirely new idea (eg Tobin (1985)), the recent debate has been motivated by a number of factors. These include: (i) interest in technological innovations for the financial sector; (ii) the emergence of new entrants into payment services and intermediation; (iii) declining use of cash in a few countries; and (iv) increasing attention to so-called private digital tokens. In response to the growing interest of central banks, the private sector and the public at large, the Committee on Payments and Market Infrastructures (CPMI) and the Markets Committee (MC) conducted complementary studies on the implications of issuing a central bank digital currency (CBDC).

This consolidated report is an early contribution to this topic, providing a conceptual analysis of the potential effect of CBDC in three core central banking areas: payments, monetary policy implementation and financial stability. The committees' work in this area builds on previous work they conducted on the role of central bank money, digital currencies, fast payments, access to central bank services and monetary policy implementation.[1] It is complemented by an exploration of possible effects on the structure of the financial system and for financial stability.

CBDC raises questions about the role of central bank money, direct access to central bank liabilities and the structure of financial intermediation. Traditionally, central banks have, for various reasons, tended to limit access to (digital) account-based central bank money to banks and, in some instances, to certain other financial or public institutions.[2] By contrast, physical central bank money (ie cash) is widely accessible. In some jurisdictions, however, the use of cash is decreasing, with the possibility of its complete disappearance, implying that the public would no longer have wide access to central bank money. Since the traditional approach has, in general, served the public and the financial system well, the bar for changing the current monetary and financial structure is high.

The report is organised as follows. Section 2 introduces a taxonomy of CBDC, provides an overview of key design features and describes two variants: a wholesale and a general purpose variant. The two are used as reference cases to analyse the payment system implications in Section 3, as well as the impact on monetary policy implementation and transmission in Section 4. Section 5 discusses the broader implications for the financial system, financial stability risks and cross-border issues.

2. Taxonomy

CBDC is not a well-defined term. It is used to refer to a number of concepts. However, it is envisioned by most to be a new form of central bank money. That is, a central bank liability, denominated in an existing unit of account, which serves both as a medium of exchange and a store of value. This would be an innovation for general purpose users but not for wholesale entities. Central banks already provide digital money in the form of reserves or settlement account balances held by commercial banks and certain other financial institutions at the central bank. This mix of new and already existing forms of central bank money makes it challenging to precisely define what a CBDC is. In fact, for purposes of analysing what may change,

[1] See also CPSS (2003), CPMI (2012), CPMI (2014), CPMI (2015) and CPMI (2016a, 2016b).

[2] In the early days of central banking, it was fairly common to offer accounts not just to banks but also to non-banks (see eg Reichsbank (1926) and Bank of England (1963)). However, starting in the 20th century, central banks have tended to progressively restrict access by non-banks. In recent years, access has been granted to some critical financial market infrastructures (FMIs), such as central counterparties (CCPs), mainly for financial stability purposes. Moreover, some central banks have provided access to liquidity-absorbing instruments, such as central bank bills and reverse repos, to a broader set of counterparties than banks.

it is easier to define a CBDC by highlighting what it is not: a *CBDC is a digital form of central bank money that is different from balances in traditional reserve or settlement accounts.*[3]

2.1 The money flower

To get greater clarity, it is useful to put CBDC in the context of other types of money. Graph 1 presents a taxonomy of money in the form of a Venn-diagram referred to as the *money flower* (Bech and Garratt (2017)). The version here focuses on the combinations of four key properties: *issuer* (central bank or other); *form* (digital or physical); *accessibility* (widely or restricted); and *technology* (token- or account-based).[4] Money is typically based on one of two basic technologies: *tokens of stored value* or *accounts* (Green (2008) and Mersch (2017a)). Cash and many digital currencies are token-based, whereas balances in reserve accounts and most forms of commercial bank money are account-based.

A key distinction between token- and account-based money is the form of *verification* needed when it is exchanged (Kahn and Roberds (2009)). Token-based money (or payment systems) rely critically on the ability of the payee to verify the validity of the payment object. With cash the worry is counterfeiting, while in the digital world the worry is whether the token or "coin" is genuine or not (electronic counterfeiting) and whether it has already been spent.[5] By contrast, systems based on account money depend fundamentally on the ability to verify the identity of the account holder. A key concern is identity theft, which allows perpetrators to transfer or withdraw money from accounts without permission.[6] Identification is needed to correctly link payers and payees and to ascertain their respective account histories.

Digital central bank money is at the centre of the money flower. The taxonomy distinguishes between three forms of CBDCs (the dark grey shaded area). Two forms are token-based and the other is account-based. The two token-based versions differ first and foremost by who has access, which, in turn, depends on the potential use of the CBDC. One is a widely available payment instrument that is primarily targeted at retail transactions but also available for much broader use.[7] The other is a restricted-access digital settlement token for wholesale payment and settlement transactions. Below they are referred to as (central bank) *general purpose token* and (central bank) *wholesale token*.

The account-based version envisages the central bank providing *general purpose accounts* to all agents in the jurisdiction. While the scale would be of a different magnitude, the technology to do so is arguably currently available. The novelty would be the decision to implement such accounts.

[3] Reserves and settlement accounts are available in most jurisdictions to "monetary policy counterparties", ie financial institutions that are directly relevant for monetary policy implementation, such as deposit-taking entities, which are generally already granted access to central bank deposit and lending facilities. In some jurisdictions, account holders may comprise a broader group and include non-monetary counterparties (eg treasury, foreign central banks or certain financial markets infrastructures (FMIs)). Some central banks are considering widening access. CBDC would further expand access to digital central bank money but not to central bank lending facilities.

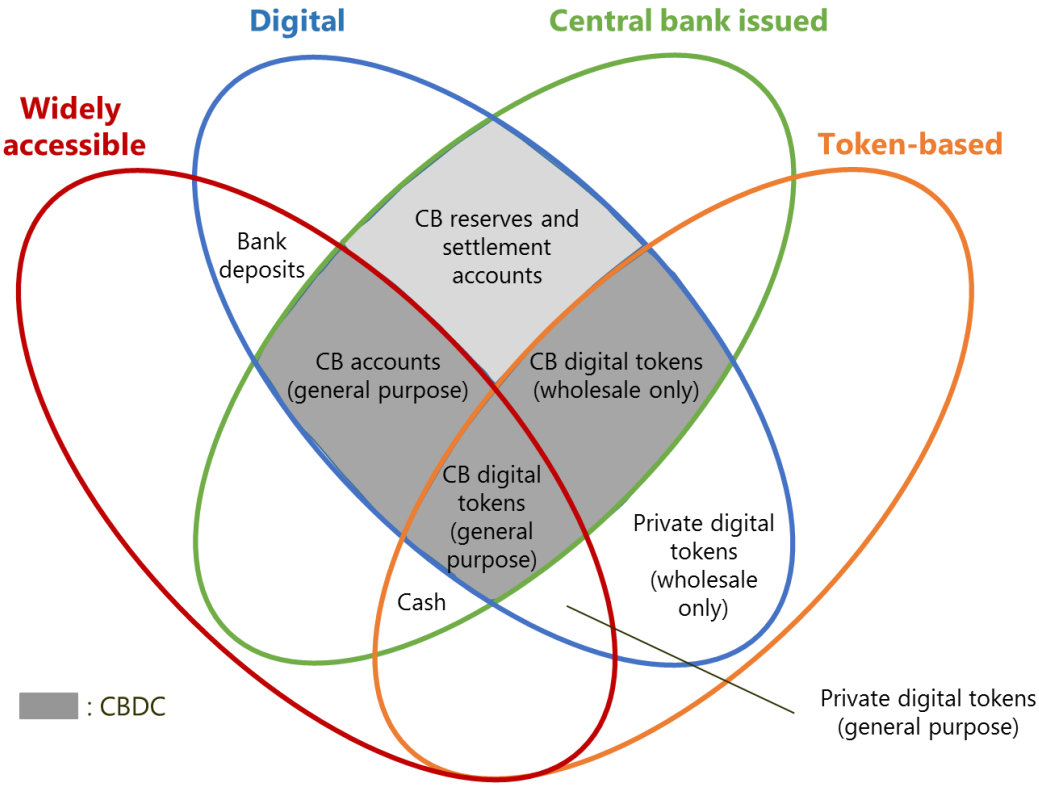
[4] Accessibility distinguishes between money that is available everywhere to everyone and money that is restricted to certain agents or jurisdictions.

[5] Double-spending is a potential problem for digital tokens. There is a risk that a payer could try to use the "same" token on two different transactions.

[6] The incident that occurred in February 2016 at the central bank of Bangladesh is an example of false verification based on compromised credentials. CPMI (2017b) presents a strategy to counter fraud in wholesale payment systems. In general, safeguarding against unauthorised access or tampering of account histories is of utmost importance. If someone maliciously breaks into the trusted intermediary hosting all the account balances, they can in principle tamper or modify any account balances at will. CPMI and IOSCO (2016) provides guidance on cyber-resilience for financial market infrastructures.

[7] It is common to divide payments into retail and wholesale segments. Retail payments are relatively low-value transactions, in the form of, for example, cheques, credit transfers, direct debits and card payments. By contrast, wholesale payments are large-value and high-priority transactions, such as interbank transfers. The distinction might become less relevant in a world with CBDCs. In fact, depending on its design, a widely available CBDC could also be used for wholesale transactions.

The money flower: a taxonomy of money Graph 1



Notes: The Venn-diagram illustrates the four key properties of money: *issuer* (central bank or not); *form* (digital or physical); *accessibility* (widely or restricted) and *technology* (account-based or token-based). *CB* = central bank, *CBDC* = central bank digital currency (excluding digital central bank money already available to monetary counterparties and some non-monetary counterparties). *Private digital tokens (general purpose)* include crypto-assets and currencies, such as bitcoin and ethereum. *Bank deposits* are not widely accessible in all jurisdictions. For examples of how other forms of money may fit in the diagram, please refer to the source.

Source: Based on Bech and Garratt (2017).

2.2 Design features

In addition to the four core properties highlighted above, there are other design features that will determine how a CBDC may serve as a means of payment and a store of value. These choices will have implications for payments, monetary policy and financial stability. The most important CBDC design options identified to date are listed below. Table 1 provides a comparison of properties across existing and potential new forms of central bank money.

Availability. Currently, access to digital central bank money is limited to central bank operating hours, traditionally less than 24 hours a day and usually five days a week.[8] CBDCs could be available 24 hours a day and seven days a week or only during certain specified times (such as the operating hours of large-value payment systems). CBDC could be available permanently or for a limited duration (eg it could be created, issued and redeemed on an intraday basis).

[8] The introduction of faster or instant payment systems in an increasing number of jurisdictions has led a number of central banks to reconsider the time during which access to digital central bank money is available, with some moving toward availability 24 hours a day seven days a week for central bank money settlement of fast retail payments (see CPMI (2016b) and Bech et al (2017)).

Key design features of central bank money — Table 1

	Existing central bank money		Central bank digital currencies		
	Cash	Reserves and settlement balances	General purpose token	accounts	Wholesale only token
24/7 availability	✓	×	✓	(✓)	(✓)
Anonymity vis-à-vis central bank	✓	×	(✓)	×	(✓)
Peer-to-peer transfer	✓	×	(✓)	×	(✓)
Interest-bearing	×	(✓)	(✓)	(✓)	(✓)
Limits or caps	×	×	(✓)	(✓)	(✓)

✓ = existing or likely feature, (✓) = possible feature, × = not typical or possible feature.

Anonymity. Token-based CBDC can, in principle, be designed to provide different degrees of anonymity in a way that is similar to private digital tokens.[9] A key decision for society is the degree of anonymity vis-à-vis the central bank, balancing, among other things, concerns relating to money laundering, financing of terrorism and privacy.

Transfer mechanism.[10] The transfer of cash is conducted on a peer-to-peer basis, while central bank deposits are transferred through the central bank, which acts as an intermediary. CBDC may be transferred either on a peer-to-peer basis or through an intermediary, which could be the central bank, a commercial bank or a third-party agent.

Interest-bearing. As with other forms of digital central bank liabilities, it is technically feasible to pay interest (positive or negative) on both token- and account-based CBDCs. The interest rate on CBDC can be set equal to an existing policy rate or be set at a different level to either encourage or discourage demand for CBDC.[11] Both non-interest bearing and interest bearing accounts could be used for retail or wholesale payment transactions. The payment of (positive) interest would likely enhance the attractiveness of an instrument that also serves as a store of value.

Limits or caps. Different forms of quantitative limits or caps on the use or holdings of CBDC are often mentioned as a way of controlling potentially undesirable implications or to steer usage in a certain direction. For example, limits or caps could make a CBDC less useful for wholesale rather than retail payments. At present, such limits or caps on holdings/use are most easily envisioned in non-anonymous account-based systems.[12]

[9] For example, bitcoin allows transactions to be (pseudo) anonymous. While all bitcoin transactions are publicly recorded using the payer's and the payee's public addresses, very much like e-mail addresses, these addresses do not necessarily reveal the true identity of users. A person sending bitcoin to a public address thus need not reveal his/her true identity to the recipient (counterparty anonymity) or to other users (one form of third-party anonymity). Recent innovations may allow even more anonymity than in the original bitcoin design.

[10] Bech and Garratt (2017) focus on the transfer mechanism (centralised or decentralised) rather than on the token- or account-based technology. Money is either exchanged in a decentralised manner known as peer-to-peer (ie transactions occur directly between the payer and the payee without the need for a central intermediary) or in a centralised manner relying on the services of one or more third parties. Tokens are often transferred peer-to-peer.

[11] Moreover, rates could be differentiated. For example, if accounts were linked to individual persons or entities, the CBDC rate could vary by counterparty, amount held in the account or some other characteristic, in a way that is similar to the current central bank practice of extensive use of differentiated interest rates on deposits held by non-monetary counterparties.

[12] The proper functioning of the payment system, however, implies one-to-one convertibility of CBDC with respect to reserves and banknotes (Fung and Halaburda (2016)). Not facilitating one-to-one convertibility would lead to an exchange rate between different types of central bank money, breaking the unity of the currency. However, some have proposed allowing this unity to break under certain circumstances. For example, Agarwal and Kimball (2015) propose abandoning one-to-one convertibility as a way of allowing a floating exchange rate between cash and commercial bank deposits and thus eliminating the effective lower bound. Abandoning convertibility between CBDC and reserves would similarly lead to a floating exchange rate between CBDC and commercial bank deposits.

The different combinations of features mean that there are many potential CBDC variants. The two variants analysed below – one with restricted access for wholesale payments and one with wide access for general purposes (either token- or account-based) – are presented for conceptual clarity purposes only; they are by no means exhaustive.

3. Payment aspects

The introduction of a *general purpose* or a *wholesale only* CBDC could bring a number of potential benefits to payment, clearing and settlement systems, but it could also pose several risks and challenges. In deciding the case for CBDCs, central banks should compare them with existing or enhanced payment, clearing and settlement solutions. And they would need to consider the impacts on other parts of their remit – most importantly monetary policy and financial stability (analysed in the next two sections).

3.1 General purpose CBDC

One rationale for introducing CBDC in a jurisdiction could be to provide a safe, central bank instrument, especially should the use of cash decline significantly. Over the past decades, technological developments have significantly improved the convenience and efficiency of digital forms of private sector payment instruments compared with central bank paper money (ie banknotes). In Sweden, these developments have led to an absolute decline in the amount of cash in circulation. The Riksbank is investigating whether an e-krona would provide the general public with continued access to central bank money and increase the resilience of the payment system (Skingsley (2016) and Sveriges Riksbank (2017)).[13]

While specifics will vary according to a country's circumstances and economic conditions, these payment-related motivations for issuing CBDC appear at this time not to be compelling for most jurisdictions. The growing use of electronic means of payment has generally not yet resulted in a substantial reduction in the demand for cash (Graph 2).[14] The rationale for considering a central bank replacement for, or supplement to, cash thus may appear less compelling (CPMI (2017a)). The efficiency gains for retail payment purposes may also be less material. In many countries, current retail payment solutions are convenient, efficient and reliable, and have earned public trust and confidence over time.

Going forward, technology will likely offer even more opportunities to enhance convenience, increase safety, lower overall costs and further improve resilience. A number of jurisdictions have already adopted or are in the process of addressing public demand for faster and more convenient approaches to payments that are also compatible with new digital and mobile technologies. Some are already providing real-time or near real-time settlement and close to 24/7 availability. One exception is perhaps cross-border retail payments, which are generally slower, less transparent and more expensive than domestic retail payments (CPMI (2018)).

Some argue that CBDC could also reinforce the resilience of a country's retail payment systems. They argue that should payments in private sector infrastructures be disrupted due, say, to technical problems or because a bank providing credit transfers was under stress, households and businesses could still make digital payments via CBDC, something especially important if cash had (largely) disappeared. On a related note, CBDC could reduce the concentration of liquidity and credit risk in payment systems (Dyson and Hodgson (2016)). However, one could, of course, also achieve operational resilience through the diversity afforded by multiple payment systems, although this could be difficult to achieve given the network effects and economies of scale present in payment systems. In addition, continued availability and use of physical currency could help ensure even greater resilience by providing an instrument that is more immune to disruptions to electric power and telecommunication networks resulting from natural or man-made

[13] Cash use has declined to the point where a growing number of merchants no longer accept cash and most bank branches have eliminated cash processing (Skingsley (2016)).

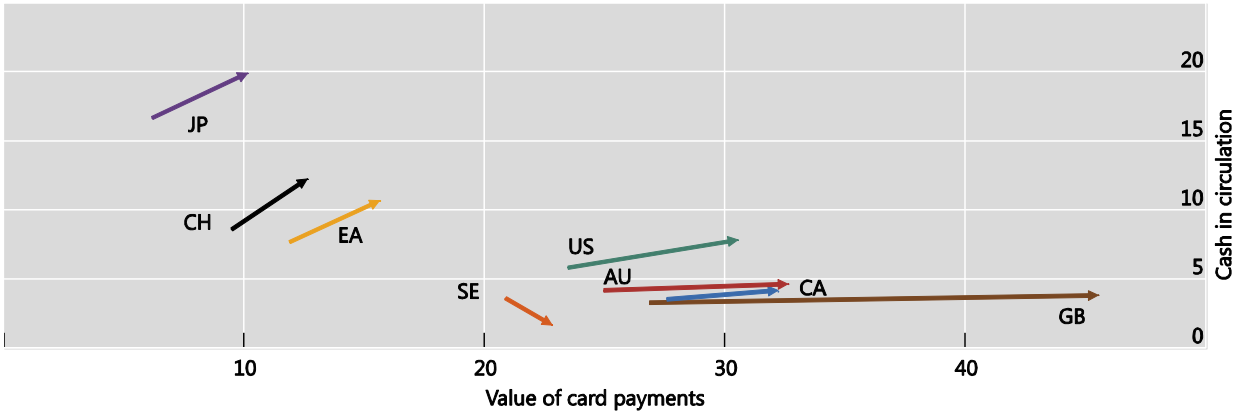
[14] Unfortunately, internationally comparable data are not available on the actual use of cash, only for cash in circulation.

disasters. Having said that, in those jurisdictions where the general public is abandoning cash, this is not an alternative.

Card payments and cash demand, change 2007–16[1]

Graph 2

As a percentage of GDP



[1] The start of an arrow represents 2007 data while the end represent 2016

Source: Bech et al (2018).

In this context, one could also consider the implications of not issuing CBDC. One is the potential for private digital tokens to more widely displace central bank money in transactions. Retail customers could face more credit and liquidity risks, relative to central bank liabilities, from exposure to either private issuers of digital tokens or from a lack of issuer. At this time, their volatile valuations and inadequate investor and consumer protection make private digital tokens unsafe to rely on as a common means of payment and a stable store of value or unit of account. Overall, while carefully monitoring the development and potential uses of new technologies, central banks are likely to continue to emphasise the need for improving the efficiency and speed of private systems.

3.2 Wholesale-only CBDC

In terms of wholesale markets, the main argument made is that settlement systems for financial transactions could be made more efficient – in terms of operational costs and use of collateral and liquidity – and more secure by using wholesale CBDC. Introducing a wholesale CBDC that is comparable to traditional central bank reserves into interbank payment systems could potentially improve efficiency and risk management in settlement (see CPMI (2017a)). If complemented by direct participation of non-banks in the settlement process, gains could further increase, including through facilitating the use of new technologies for asset transfers, authentication, record-keeping, data management and risk management. Payments and (cash legs of) securities transactions settled in CBDC, instead of through facilities hosted by commercial banks or other service providers, could help reduce counterparty credit and liquidity risks in the financial system. It could also help central banks monitor financial activity.

To meet evolving needs from financial markets and to ensure an overall stable and sound financial system, a number of central banks have been conducting experiments involving CBDC and its related underlying technology (in particular DLT). Early experimentation, however, has not shown significant benefits for wholesale payments. The design of an infrastructure using such new technology would look similar to the one currently in place in terms of legal, operational and security requirements. Doubts remain regarding the maturity of the technology and the size of efficiency gains associated with the use of DLT. Moreover, changes could imply expanded – direct or indirect – access to a central bank account with new counterparties, which could be difficult to control. That said, technologies and related possible designs are evolving quickly and central banks will need to continually assess whether introducing CBDC (potentially incrementally) in this area could be useful.

3.3 Other considerations

In addition to more efficient and safer payments and settlement systems, CBDC could come with additional benefits. Given that a CBDC can allow for digital records and traces, it could improve the application of rules aimed at anti-money laundering and countering the financing of terrorism (AML/CFT), and possibly help reduce informal economic activities. These gains may, however, be small in that the formal payment system, especially if there were to be a traceable CBDC, would not necessarily be the main conduit for illicit transactions and informal economic activities.

There are also costs. Commercial banks could lose a valuable interface with their consumers given that in some CBDC designs the "know-your-customer" function could fall to the central bank. Central banks would have to take on a much larger role in this field, with associated costs. Central banks could also be called upon to provide information to tax and other authorities (eg for judicial matters). Moreover, they would have to manage privacy and anonymity issues stemming from the insights obtained from private transactions. More generally, central banks might have to deal with many requests and customers, including some now excluded, for which they are not necessarily well equipped (although some of these challenges may be mitigated or avoided by careful design).

Another argument is that a CBDC could improve financial inclusion. In some countries, a sizable portion of the population does not participate in the formal financial system and could thus miss out on associated benefits. A CBDC, however, does not necessarily alleviate all the constraints to access; for some segments of the population, barriers to the use of any digital currency may be large, and the preference for trusted alternatives, such as cash, is strong. In addition, a CBDC may allow for better real-time data on economic activity but such gains are already largely achievable with existing payments data. A more persuasive argument is that a CBDC may help to maintain a direct link between central banks and citizens (especially where cash use is diminishing), which could help foster the public's understanding of central banks' roles and need for independence (Mersch (2017b)).

3.4 Key feasibility and operational challenges

Even if CBDCs were deemed desirable, initial exploration and experimentation have identified a number of legal, technical and operational issues that central banks and other relevant parties must consider before an instrument can be deemed suitable for wide-scale use.

In some countries, there are **legal considerations**. Not all central banks have the authority to issue digital currencies and expand account access, and issuance may require legislative changes, which might not be feasible, at least in the short term. Other questions include whether a CBDC is "legal tender" (ie a legally recognised payment instrument to fulfil financial obligations) and whether existing laws pertaining to transfers of value and finality are applicable.[15]

Central banks would also have to take account of **AML/CFT concerns and requirements** if they were to issue CBDC. Issuing a CBDC that does not adequately comply with these and other supervisory and tax regimes would not be advisable. To date, it is not clear how AML/CFT requirements can be implemented practically for anonymous forms of CBDC. Forms of CBDC that can be easily transferred across borders or used offshore are especially likely to present significant challenges in this respect. As such, the reputational risk to the central bank from a general purpose CBDC must be considered.

The use of central bank and commercial bank deposits typically provides some level of privacy (for individual banks and agents, respectively), while the use of cash provides anonymity to all users. The appropriate degree of privacy, as also judged by society, is a challenge in a digital environment. For CBDC,

[15] Existing laws are typically written broadly for direct physical transfer or for a central entity ("banks") to accept instructions and modify a ledger. In a CBDC based on DLT, multiple entities could modify a set of distributed ledgers. Other legal issues, such as the timing of the discharge of obligations and liability for errors and unauthorised payments, may also be relevant.

the appropriate degree of privacy of the currency would need to be considered carefully, which could entail difficult public policy design choices for a central bank.

Cyber-security is currently one of the most important operational challenges for central bank systems and the financial industry more generally. Cyber-threats, such as malware, and fraud are risks for nearly every payment, clearing and settlement system. They pose, however, a particular challenge for a general purpose CBDC, which is open to many participants and points of attack. Moreover, the potential effect of fraud could be more significant because of the ease with which large amounts could be transferred electronically. Robust mitigation methods of cyber-risk would therefore be a prerequisite for CBDC issuance.

More generally, the **robustness of possible new technologies** in ensuring a sound risk management framework is uncertain. Because central bank services are essential to the smooth functioning of an economy, very robust requirements for reliability, scalability, throughput and resilience are necessities. Central banks therefore typically have very rigorous operational requirements for their systems and services. Some of the proposed technologies for issuing and managing CBDC (such as DLT) are still relatively untested, and even the private sector is in the early phase of developing and applying DLT for commercial use.[16] Many questions surrounding operational risk management and governance need to be answered before deployment can be envisioned. This may especially be the case for countries at earlier stages of financial infrastructure development.

4. Monetary policy aspects

The consequences of CBDC issuance for the implementation and transmission of monetary policy are directly related to how wide access to CBDC is and whether it is attractively remunerated. Monetary policy arguments for issuing CBDC include potential strengthening of the pass-through of the policy rate to money markets and deposit rates, and helping to alleviate the zero (or effective) lower bound constraint. These arguments should be considered carefully. It is not clear that the pass-through of the policy rate needs strengthening and introducing a CBDC may also bring new risks to monetary policy. In addition, existing tools can, in many cases, achieve the same objectives. Since digital central bank money is already available to monetary counterparties and some non-monetary counterparties, as discussed in other sections, this section refers only to the monetary policy aspects introduced by wider access to CBDC.[17]

4.1 Desirability for monetary policy

Wider digital access to the central bank may strengthen the pass-through of the policy rate to money and lending markets. Monetary policy implications are likely more pronounced if CBDC emerges as an attractive asset to hold. The crucial design features that determine the extent to which CBDC may function as such include the rules regulating its access by different types of agent, its availability beyond intraday use and whether it is interest-bearing, and at what rate (Box A). Only if it combines these choices, would it be a new and liquid central bank liability likely to have an impact on the channels of transmission of policy rates to the money market and beyond.

[16] Any CBDC need not necessarily be implemented using some form of DLT; theoretically more traditional centralised technologies may suffice. The pros and cons of using DLT in general, eg as regard to scalability, confidentiality and resilience, is an area of ongoing research that is outside the scope of this report.

[17] Besides the fact that digital central bank money is already provided to monetary counterparties, and merely changing the technology behind the provision of funds is thus of limited significance, there are three reasons for this delineation. First, while central banks may need to adjust the quantity of money provided to monetary counterparties to control short-term interest rates, the demand for central bank money held by non-monetary counterparties (eg treasury, foreign central banks or certain FMIs) is more typically just accommodated. Second, there may be good reasons for central banks to provide digital central bank money on different terms (remuneration, settlement hours, individual quantitative limits and anonymity) to (various) monetary and non-monetary counterparties. Third, while monetary counterparties have some access to intraday and overnight credit (ie reserve balances may turn negative), non-monetary counterparties typically do not. Similarly, CBDC balances may not turn negative.

Box A

Features of CBDC, demand and the degree of substitution with other financial assets

The way in which access to CBDC is granted implies that substitution effects will affect different types of financial asset. CBDC accessible to individuals and designed as a non-interest bearing, retail payment instrument might primarily substitute for cash (eg token-based CBDC) and commercial bank deposits (eg account-based CBDC). CBDC that pays interest and is readily transferable would likely be attractive to professional financial market participants (eg cash pools and asset managers). It may substitute for money market instruments, such as government bills, reverse repos, central bank bills and FX swaps, and be a liquid and credit risk-free asset facilitating final settlement. CBDC accessible to non-residents may substitute for internationally-used banknotes, bank deposits and international reserve assets. Substitution may theoretically be limited by imposing individual quantitative limits in normal times, eg access could be conditional upon a commercial bank account to which payments are redirected in case this upper limit is surpassed, to try to curb demand.①

Substitution effects will be importantly influenced by whether a CBDC is non-remunerated (as is cash), whether it pays interest at an unchangeable or adjustable rate and whether that rate might possibly move with the policy rate, and, if so, at a spread that is constant or varying. Moreover, rates could be differentiated. A substantially lower interest rate on CBDC holdings exceeding, say, the amount covered by deposit insurance schemes would reduce their attractiveness in normal times.

These and other design features will influence the demand for CBDC. If designed with limited attractiveness, the substitution effects in normal times may be moderate, and so will be the effects on monetary policy transmission (as well as any structural effects on the financial system). Of course, in times of stress, central banks are unlikely to want to directly control the quantity of CBDC because they would want to maintain one-to-one convertibility with respect to reserves and banknotes.②

Even if purposefully designed to be primarily a payment vehicle, CBDC may still end up functioning like a store of value in unforeseen ways under certain circumstances. In times of financial stress, domestic (retail) investors are likely to consider CBDC attractive relative to bank deposits, with many possible side effects, including for financial stability (see section 5). And, if granted access, residents in high-inflation countries may turn to CBDC issued by a low-inflation country (as they do nowadays with cash).

① An application of overall quantitative limits to CBDC may potentially disrupt payment systems, giving rise to an exchange rate between different types of central bank money. Such issues may not occur in the case of individual quantitative limits. However, the aggregate of individual limits could in theory produce a binding overall limit in certain situations. ② The one-to-one convertibility between CBDC, banknotes and reserves means that the central bank can only control their joint quantity. While the central bank can, in principle, steer the overall quantity of central bank money outstanding through liquidity-injecting and liquidity-absorbing open market operations, the holders of central bank money jointly determine its composition, as they are free to convert one type of liability into another. Commercial banks face a similar issue in not being able to directly control the quantity of their retail deposits. This illustrates that means of payment cannot be directly quantitatively controlled but are rather indirectly influenced by their design features and adjustments in other items. Central banks already face this issue in the provision of banknotes, reserves and deposits for a relatively small number of non-monetary counterparties (see Annex A). Traditionally, central banks passively and elastically accommodate the demand for banknotes and deposits held by non-monetary counterparties to steer the quantity of reserves. This is a necessary condition for implementing monetary policy and it would apply with equal force to CBDC.

In particular, a CBDC attractively remunerated compared with other interest rates could affect holdings by institutional investors of other liquid, low-risk instruments (such as short-term government bills and repos backed by sovereign collateral).[18] If institutional investors could hold such an instrument without limits, the interest rate on it would help establish a hard floor under money market rates, which is arguably useful.[19]

An interest-bearing general purpose variant could also make pass-through more direct. If households considered a CBDC to be an alternative to commercial bank deposits, banks would have less scope for independently setting the interest rate on retail deposits. For example, banks would find it harder not to

[18] Note also that this refers to the general collateral (cash-driven) segment of repo markets, not to the "specials" (collateral-driven) segment.

[19] Duffie and Krishnamurthy (2016), who do not explicitly mention CBDC as a possible instrument, argue that the dispersion of rates that is related to imperfect pass-through signals a social cost.

increase deposit rates in tandem when the central bank was raising the CBDC rate. As such, a change in the policy rate could be more directly transmitted to bank depositors (possibly with an intermediation margin, given costs and credit risks). To the extent that an attractively remunerated CBDC reduced currency substitution, which is a possibility in some countries, pass-through more generally could be enhanced, including with respect to domestic prices.

In principle, negative rates on central bank liabilities could provide the monetary stimulus needed in extreme circumstances. Proponents have suggested that issuance of CBDC could serve to alleviate the zero lower bound if it came along with a reduced desire for cash holdings (eg Goodfriend (2016) and Dyson and Hodgson (2016)). Relatedly, some argue that having a substitute for cash in the form of (interest-bearing) CBDC makes the discontinuation of higher denomination banknotes easier to achieve (Rogoff (2016) and Bordo and Levin (2017)).[20]

There are, however, important caveats and counter-arguments. The degree to which key market rates move in conjunction with the policy rate appears satisfactory for most central banks. Whether the pass-through to money markets, for example, is impeded in material ways is not clear (Potter (2017)). Moreover, it is not clear whether one should expect bank deposit rates to respond immediately to policy rate changes. The spreads between the policy rate and retail rates represent compensations for various risks and transaction costs, including for services that are implicitly cross-subsidised (commercial banks provide a broader range of services to retail investors than any CBDC would). More generally, retail depositors tend to be less price-sensitive than wholesale investors. And, the stickiness of retail deposits allows commercial banks to perform more easily their maturity, credit risk and liquidity transformation roles in the economy.

In practice, the lack of a one-to-one response to policy rate hikes and cuts does not represent a challenge as long as central banks have appropriate control over financial conditions. Banks take into consideration a wider range of factors than simply the policy rate in the pricing of their retail deposits, including longer-term rates that encompass credit and liquidity risk premia (ie they look at the relevant investment opportunities). That said, the presence of an attractive CBDC would put pressure on commercial banks to raise their retail deposit rates to avoid losing retail funding. At the same time, some doubt that additional tools would strengthen the central bank's ability to achieve its objectives (eg Bindseil (2016)). Moreover, even if pass-through warrants strengthening, there are other conventional tools, such as central bank bills, time deposits and standing reverse repo facilities (Box B) that can accomplish the same objective.

Box B

Central bank bills, time deposits and standing repo facilities as alternatives to CBDC

Strengthening the pass-through of the policy rate to money market rates also could be achieved by the central bank supplying liquidity-absorbing instruments to non-bank money market participants. The latter includes reverse repo facilities, time deposits and central bank bills. Central banks have significant expertise and experience in the use of such tools. Considering the pros and cons of these alternatives, there are two key differences between offering liquidity-absorbing instruments and CBDC to money market participants:

- CBDC can be used as intraday liquidity by its holders, whereas liquidity-absorbing instruments cannot achieve the same, or can do so only imperfectly. At the moment, there is no other short-term money market instrument featuring the liquidity and creditworthiness of CBDC. The central bank would thus use its comparative advantage as a liquidity provider when issuing CBDC.
- Although the quantity of CBDC can be influenced by its design features, it cannot be fully controlled. By contrast, liquidity-absorbing instruments can be auctioned off in fixed quantities.

While a CBDC could carry a negative rate, this may not address effectively the zero lower bound if higher denomination banknotes were not simultaneously abolished (eg Pfister (2017)). More generally, considering political economy consequences, it is uncertain how deeply negative rates may work in

[20] Also, some have argued that CBDC could enhance the effectiveness of quantitative easing, given that monetary counterparties would no longer have to intermediate when the central bank conducted asset purchases (eg bonds would be swapped for risk-free CBDC) instead of dealing in credit-risky commercial bank deposits, possibly strengthening any portfolio rebalancing effects.

practice, (McAndrews (2017)). Finally, weaker demand for cash does not imply the need for a CBDC. In fact, monetary policy can still remain effective even without cash (Woodford (2000)). On balance, it is not clear that there is a strong basis at this time to issue a CBDC for the purpose of enhancing the efficacy of monetary policy transmission.

4.2 Implications for monetary policy implementation and interest rates

The presence of CBDC would have a limited impact on monetary policy implementation – that is, how central banks use their balance sheets to control short-term interest rates (for a review see Annex A). While a central bank would need to accommodate demand for CBDC, flows into CBDC would drain the amount of reserves in the system in exactly the same way as flows into banknotes and central bank deposits held by non-monetary counterparties (eg the treasury, foreign central banks or financial market infrastructures (FMIs)) currently do. In a corridor system, all flows in and out of CBDC need to be compensated through liquidity-injecting and liquidity-absorbing open market operations (OMOs) to keep the desired amount of reserves.[21] In a floor system, only when CBDC inflows drained reserves to the point where they became scarce would the central bank need to undertake additional liquidity-injecting OMOs.

Therefore CBDC does not alter the basic "mechanics" of monetary policy implementation (see further Annex B for a flow-of-funds representation). Demand for CBDC would just be another factor to consider for policy responses to be consistent with continued control over short-term interest rates. There are two practical implications, though. First, depending on the degree of substitution, a larger balance sheet may be needed to implement monetary policy, as agents substitute physical cash, commercial bank deposits and other safe assets for CBDC. Second, the overall volatility of autonomous factors could be affected, which, in turn, may affect their predictability.[22]

While likely requiring larger balance sheets, central banks would still have discretion in choosing the assets they hold to accommodate the demand for CBDC, just as they have for banknotes. Theoretically, assets can be made up of outright holdings of any kind or collateralised lending to monetary counterparties on any terms and conditions.[23] Subject to the overall supply of various types of asset and changes thereof, the additional duration, liquidity and credit risk stemming from accommodating the demand for CBDC is thus determined by the central bank itself, as is the case with banknotes.

Demand for CBDC may be volatile on a daily basis, as inflows and outflows result from payments between CBDC and non-CBDC holders. Whether this leads to higher overall volatility depends on the correlations with other factors.[24] If volatility proves particularly high, central banks can be forced to operate through a floor system. Whether the quality of liquidity forecasting is hampered depends on the predictability of daily flows in and out of CBDC.

The overall effects of CBDC on the (term) structure of interest rates are very hard to predict and will depend on many factors. To attract demand, short-term government paper and overnight repos with treasury collateral might have to provide some yield pickup with respect to a wholesale-oriented

[21] Under a corridor system, the (marginal) CBDC remuneration rate should not exceed the policy rate. Otherwise, monetary counterparties would have an incentive to trade their excess overnight funds with CBDC holders instead of trading them among themselves. Monetary counterparties with temporary liquidity deficits would need to bid up overnight rates, causing short-term interest rates to exceed the policy rate. Under a floor system, the marginal CBDC rate should not exceed the rate of remuneration of reserves placed at the central bank's deposit facility.

[22] CBDCs are considered an autonomous factor for monetary policy implementation for two reasons. First, from the viewpoint of the day-to-day steering of the central bank's balance sheet to control short-term interest rates, daily fluctuations in the demand for CBDC are an exogenous factor, even though CBDC would be an endogenous factor within the broader monetary policy framework. Second, even if CBDC was introduced, the amount of digital central bank money held by monetary counterparties (reserves) would still be crucial for control over short-term interest rates.

[23] As central bank credit to monetary counterparties is collateralised, a widening of collateral eligibility may be necessary to accommodate banks' increased recourse to credit facilities to compensate for the loss of funding due to CBDC inflows (Annex B).

[24] In the case of a corridor system, this may necessitate more frequent liquidity-injecting and liquidity-absorbing OMOs, higher reserve requirements with averaging provisions or wider tolerance bands around reserve targets to steer liquidity conditions.

remunerated CBDC. This means that the short end of the sovereign yield curve may end up above the CBDC rate. Contrary to the hard floor that the wholesale CBDC variant may put under money market rates, the general purpose variant is likely to put only a soft floor under retail deposit rates given the lower price sensitivity of retail depositors and switching costs.

At the same time, depending on the specific assets held to accommodate the issued CBDC, central banks would probably need to engage in various kinds of maturity, liquidity and credit risk transformation. How these two forces balance out in terms of various interest rates across assets classes and maturities is difficult to predict. More generally, the implications of a CBDC relative to other instruments are likely to depend on each jurisdiction's specific operating environment. Also, since operating environments may change in the future, monetary policy cost-benefit analyses related to CBDC may need to be revisited periodically.

5. Financial intermediation, financial stability and cross-border aspects

Whether or not to introduce a CBDC depends on an assessment of many fundamental issues that go beyond the impact on the payment system and monetary policy transmission and implementation. In this section, topics warranting further investigation are explored.

5.1 Role of the central bank

A fundamental matter raised by CBDC issuance relates to the appropriate roles – in financial intermediation and the economy at large – of private financial market participants, governments and central banks. With CBDCs, there could be a larger role for central banks in financial intermediation. As the demand for CBDC grows, and if holdings of cash do not decline in lockstep, central banks might need to acquire (or accept as collateral) additional sovereign claims and, depending on size, private assets (eg securitised mortgages, exchange-traded funds and others). If demand becomes very large, central banks may need to hold less liquid and riskier securities, thereby influencing the prices of such securities and potentially affecting market functioning. Central banks may also need to provide substantial maturity, liquidity and credit risk transformation at times to both banks and markets. Since central banks could assume more important roles, they could have a larger impact on lending and financial conditions.

Given that all this could challenge the two-tier banking system, structural implications need to be understood better before CBDC issuance can take place. A greater role for central banks in credit allocation entails overall economic losses if central banks are less efficient than the private sector at resource allocation (eg as it impedes the efficient use of decentralised knowledge in society (Hayek (1945)). It is doubtful, for example, that, from the perspective of an efficient allocation of credit, a centralised approach involving outright holdings of corporate securities would be preferred to a decentralised approach based on banks and other private actors granting loans to corporations and investing in securities. From an infrastructure perspective, central banks would have to decide on the design of the appropriate technology, create the required infrastructure and governance and manage this new form of money. This could lead to large operational demands and associated (upfront) costs, with the possible creation of new risks.

There could also be changes to market liquidity and interlinkages. If the demand for CBDC exceeded the decline in the demand for cash and/or reserves, larger outright holdings of CBDC could hamper market functioning if they reduced the free-floating share of outstanding bonds. While a CBDC would by itself be very liquid, it could result in reduced liquidity and increased "specialness" in collateral (repo) markets. The depth of repo and short-term government bill markets could decline as demand was redirected to wholesale market use of CBDC. While the central bank could step in on the demand side of these markets, it would need to broaden its holdings to match its increasing liabilities. This expanded role of central banks in wholesale markets could also reduce interbank activity and the price discovery role of these markets.

Coordination issues between the central bank and the government debt management office might occur and central banks' operations could become more challenging (Greenwood et al (2014)). By having to passively accommodate the demand for CBDC, the central bank could potentially introduce volatile demand for government debt. Related questions include which part of the public sector is best suited to issue a country's short-term public debt and determine the maturity profile of the consolidated public debt. If CBDC replaced a large portion of bank deposits, central bank demand for government securities could be large, which might then affect sovereign debt markets. More broadly, a larger balance sheet could present challenges as it reduced the role of the market in price setting. Such a reduction could lead to allocative distortions and tie up higher-quality assets. This could, in turn, adversely affect the functioning of collateral markets. All of this would have implications for financial stability.

Depending on design, central banks' seigniorage income could also be affected (see Annex C). Relatedly, if CBDC was interest bearing, the central bank would be directly exposed to stakeholders that might at times exert pressures to raise interest rates. Applying differentiated rates (eg by amount held or counterparty) could also be necessary for effective monetary policy implementation but this might prove to be technically difficult (eg on token-based CBDC). It could also lead to arbitrage as well as being controversial (eg a CBDC rate for households below the rate of remuneration on excess reserve balances).

5.2 Banks business models, financial intermediation and markets

The issuance of CBDC would have implications for the structure of payment markets. To the extent that a CBDC would further open up payments to non-banks, commercial banks would stand to see their payment-related income streams eroded by increased competition. Private sector FMIs, such as securities settlement systems and possibly central counterparties for securities trades, might be affected by the issuance of wholesale CBDC.[25] While such developments may be far off – because of the many legal, technical and market coordination challenges involved – market participants and authorities would need to be alert, as indirect or unintended consequences might occur.

A general purpose CBDC could have a large impact on financial intermediation patterns. The consequence of a larger central bank balance sheet could be a withdrawal of funding to commercial banks. For example, a flow of retail deposits into a CBDC could lead to a loss of low-cost and stable funding for banks, with the size of such a loss in normal times depending on the convenience and costs of the CBDC. Banks could try to prevent a loss of deposits by raising interest rates or seek funding to replace such outflows, eg through wholesale funds and term deposits, which would likely be more costly.[26] This could lead some banks to raise spreads and increase transaction fees in order to maintain profitability. Depending on existing market structures, including the importance of retail versus wholesale funding, banks might have to shrink their balance sheets, with possible adverse consequences.[27]

Commercial banks' business models would also have to adapt. Services that are currently cross-subsidised by deposits would need to become viable on a stand-alone basis. The contours of institutions undertaking the liquidity, credit risk and maturity transformation no longer performed by banks are not clear. If liquidity in financial markets were to decline and credit and term spreads were to rise, there could

[25] New applications of technology could allow participants to interact directly with a synchronised securities ledger to add, verify and report transactions, with activity to be accelerated, at least theoretically, to real-time settlement. In such a vision, central counterparties might no longer be necessary to guarantee trades between execution and settlement. A wholesale CBDC might be considered by some central banks to be part of their toolkit to improve settlements. Nonetheless, many legal, technical and market coordination challenges would need to be addressed first. Multilateral coordination and governance over such arrangements would also likely be necessary. And regulatory authorities would insist on prudent management.

[26] Furthermore, alternative means of funding are subject to uncertainties. First, the issuance of bonds by banks is contingent upon placement with investors, which may face some obstacles during times of market stress. Second, any increase in refinancing via the central bank is usually limited by the amount of assets that can be pledged as collateral with the central bank. Third, regulatory constraints may further limit the options available to compensate for the loss of deposits.

[27] Annex B contains a flow-of-funds analysis illustrating stylised static balance sheet adjustments of key sectors of the economy upon the introduction of an interest-bearing and widely accessible CBDC.

be adverse repercussions for the economy.[28] More generally, the implications of a shrinkage of commercial bank balance sheets and activity are very hard to assess and require further analysis.

A CBDC attracting significant demand as an asset to hold, may also change the structure and functioning of funding markets, affecting banks and corporations. Issuers of money market instruments and borrowers in repo markets would see more competition because a CBDC would substitute for such claims. Those who issue claims bought by the central bank to accommodate demand for CBDC would gain. Overall, there might also be a collateral upgrade for private balance sheets if central banks end up holding some less liquid and lower-rated assets to accommodate the issuance of CBDC.

5.3 Financial stability

Issuance of CBDC raises questions that are similar to those relating to narrow banking or full-reserve money, as analysed by several academics and critics of current monetary systems. Proponents claim that narrow banking could make the overall financial system safer because it limits the scope for commercial banks' operations. Although narrow banking raises many questions in its own right, the introduction of a CBDC does not necessarily entail the same restrictions.[29] While difficult to anticipate, the possibility that banks could try to offset the higher cost of funding by engaging in riskier forms of lending to restore profitability could create financial stability risks. While such risks would have to be compared with those associated with other (unconventional) monetary policy tools, and combined with the potential adverse economic impact of reduced lending (Stevens (2017)), there could be more, rather than less, financial stability risk.

In terms of wholesale markets, some (eg Greenwood et al (2016)) argue that the provision of a safe and ultra-liquid asset may help reduce rollover risks and excessive maturity transformation, potentially improving financial stability. However, whether a CBDC leads to these benefits relative to other tools is uncertain (Box C).

Arguably, the most significant and plausible financial stability risk of a general purpose CBDC is that it can facilitate a flight away from private financial institutions and markets towards the central bank. Faced with systemic financial stress, households and other agents in both advanced and emerging market economies tend to suddenly shift their deposits towards financial institutions perceived to be safer and/or into government securities. Of course, agents could always flee towards the central bank by holding more cash. But a CBDC could allow for "digital runs" towards the central bank with unprecedented speed and scale. Even in the presence of deposit insurance, the stability of retail funding could weaken because a risk-free CBDC provides a very safe alternative.

Depending on the context, the shift in deposits could be large in times of stress. A crucial element in such system-wide shifts is the stronger sensitivity of depositors to the actions of others. The more other depositors run from weaker banks, the greater the incentive to run oneself. If CBDC were available, the incentives to run could be sharper and more pervasive than today, as the CBDC would be the favoured destination, especially if deposits were not insured in the first place or deposit insurance was (made more) limited.[30] Whereas weaker banks could experience a run, even stronger banks could face withdrawals in the presence of CBDC.

[28] There are also questions in terms of microprudential regulation and supervision. Would, for example, regulatory requirements, such as capital and liquidity adequacy, and supervision of banks, need to be adapted?

[29] Narrow banking and CBDC differ in two ways. First, under CBDC residents hold direct claims on the central bank, whereas under narrow banking residents hold commercial bank money that is fully backed by central bank reserves or sovereign claims. Second, CBDC could coexist with commercial bank money, whereas narrow banking proposals envision no private money creation. Benes and Kumhof (2012) and Cochrane (2014), which represent examples of recent calls for narrow banking, also review historical precedents, such as the Chicago Plan of the 1930s. Bacchetta (2017) critically reviews such a proposal in the case of Switzerland.

[30] Although with a lower stock of demand deposits commercial banks might be less prone to retail runs, runs in recent times have been initiated by other (wholesale) creditors, which would become more important.

It would be difficult to stem runs under such conditions, even when providing large lender of last resort facilities. Changes in the interest rate that applies to CBDC are unlikely to succeed when agents seek safety at almost any price. Imposing quantitative limits, difficult at any time owing to various forms of evasion, could create price deviations between types of central bank money ("discounts"), negating the principle of money being exchangeable at par and hampering the conduct of monetary policy.

Box C

CBDC, rollover risk and financial stability

A secular rise of institutional cash pools① and a stronger desire among investors for secured forms of financing have increased the demand for highly liquid and safe instruments, which cannot be met by bank deposits (Pozsar (2011)). This has led to a "near-money premium" in wholesale markets, ie yields on short-term, liquid instruments that are significantly lower compared with those of slightly longer tenors or higher credit risk.② This, in turn, can incentivise agents to fund longer-term assets with short-term liabilities (eg repo or commercial paper), with associated rollover risks that could adversely affect financial stability.

Central banks may have a role in reducing these risks by providing non-banks with an attractive money-type instrument. As argued by some (eg Stein (2012)), the augmented supply of safe assets may force market participants to scale back their funding of longer-term assets with short-term wholesale borrowing. If less liquid and riskier money market instruments (eg commercial paper) lost some of their near-money premium, the incentives faced by issuers for maturity, liquidity and credit risk transformation could be weakened.③ Whether a CBDC would materially reduce rollover risks, however, is uncertain. Moreover, increased issuance of short-term debt by the government can also reduce the near-money premium, with possibly associated benefits. Moreover, central banks have other conventional tools at their disposal that could serve a similar purpose (Box B).

① The term "institutional cash pool" refers to large, centrally managed, short-term cash balances of global non-financial corporations and institutional investors, such as asset managers, securities lenders and pension funds. ② See eg Greenwood et al (2016) or Carlson et al (2016) for further analysis. Another way the near-money premium expresses itself is when short-term government bills and short-term repos with sovereign collateral trade significantly below the overnight index swap (OIS) rate and the policy rate. ③ For example, long positions in government bonds financed mostly in repo markets (leveraged fixed income strategies employed by hedge funds) could be unwound as collateral chains between institutional investors and money market funds are disintermediated (Pozsar (2011) and Singh (2016)).

5.4 Cross-border and global dimensions

For currencies widely used in cross-border transactions, many of the considerations outlined above would apply with added force. In normal times, there would be many complications should non-residents be allowed to hold and transact in CBDC. Distinctions between residents and non-residents and domestic and foreign transactions could become largely symbolic. For example, it could be more difficult to apply AML/CFT requirements because of a lack of formal powers over intermediaries involved in token-based CBDC distribution. Similarly, if foreign banks and FMIs (and even other central banks) were able to purchase, receive or otherwise hold "domestic" CBDC, legal and operational issues could arise. For example, a foreign entity could use the domestic CBDC to back or otherwise provide the functional equivalent of "offshore" accounts and payment services denominated in the domestic currency. Further, the more anonymous the instrument and the more decentralised the transfer mechanism was, the greater the opportunity for cross-border activity, arbitrage and concealed transactions would be, with related reputational risks for the central bank. A CBDC available cross-border could, in some economies, increase substitution away from the domestic currency, which could make monetary aggregates unstable and alter the choice of monetary instruments.

Even during normal times, CBDC could come with first-mover advantages and economies of scale and other externalities. In terms of market share, if CBDCs were introduced by jurisdictions with international currencies, they could reinforce existing costs and benefits, including externalities. Similarly, CBDC could change the nature of global liquidity and safe asset provision. Also, and especially if introduced in a sudden and unexpected manner, CBDC could, in some situations, lead to large capital movements and related exchange rate and other asset price effects. In addition, countries might face challenges in preparing for

what would happen if other central banks were to introduce CBDC. More generally, disturbances could easily occur.

The cross-border and global dimensions of CBDCs available to non-residents could be especially pronounced during times of generalised flight to safety. Under such conditions, exchanging a CBDC for an international currency could potentially enable faster deleveraging in capital markets. If CBDCs accelerated flights from risk, deleveraging pressures could manifest themselves in the form of tight funding conditions and sharp movements in foreign exchange markets.

References

Agarwal, R and M Kimball (2015): "Breaking through the zero lower bound", *IMF Working Papers*, no WP/15/224.

Bacchetta, P (2017): "The sovereign money initiative in Switzerland: an economic assessment", *CEPR Discussion Papers*, no 12349.

Bank of England (1963): "Origin of the branches." https://www.bankofengland.co.uk/-/media/boe/files/quarterly-bulletin/1963/branches-of-the-boe.pdf.

Bech, M and R Garratt (2017): "Central bank cryptocurrencies", *BIS Quarterly Review,* September, pp 55–70.

Bech, M, Y Shimizu and P Wong (2017): "The quest for speed in payments", *BIS Quarterly Review,* March, pp 57–67.

Bech, M, U Faruqui, F Ougaard, and C Picillo (2018): "Payments are a-changin' – but cash still rules", *BIS Quarterly Review*, March, pp 67-80.

Benes, J and M Kumhof (2012): "The Chicago Plan revisited", *IMF Working Papers*, no WP/12/2012.

Bindseil, U (2014): "Monetary policy operations and the financial system", Oxford University Press.

——— (2016): "Evaluating monetary policy operational frameworks", paper presented at the Economic Policy Symposium at Jackson Hole.

Bordo, M and A Levin (2017): "Central bank digital currency and the future of monetary policy", *NBER Working Papers*, no 23711.

Carlson, M, B Duygan-Bump, F Natalucci, B Nelson, M Ochoa, J Stein and S Van den Heuvel (2016): "The demand for short-term, safe assets and financial stability: some evidence and implications for central bank policies", *International Journal of Central Banking*, vol 12, no 4, December, pp 307–333.

Cochrane, J (2014): "Toward a run-free financial system", University of Chicago, working paper.

Committee on Payment and Settlement Systems (CPSS) (2003): *The role of central bank money in payment systems*, August.

Committee on Payments and Market Infrastructures (CPMI) (2014): *Non-banks in retail payments*, September.

—— (2012): *Innovations in retail payments*, May.

—— (2015): *Digital currencies*, November.

—— (2016a): *A glossary of terms used in payments and settlement systems*, October.

—— (2016b): *Fast payments – Enhancing the speed and availability of retail payments*, November.

—— (2017a): *Distributed ledger technology in payment, clearing and settlement: An analytical framework,* February.

—— (2017b): *Discussion note - Reducing the risk of wholesale payments fraud related to endpoint security - consultative document*, September.

—— (2017c): *Statistics on payment, clearing and settlement systems in the CPMI countries - Figures for 2016 (preliminary version)*, October.

—— (2018): *Cross-border retail payments*, March.

CPMI and International Organization of Securities Commissions (IOSCO) (2016): *Guidance on cyber resilience for financial market infrastructures*, June.

Duffie, D and A Krishnamurthy (2016): "Adapting to changes in the financial market landscape", paper presented at the Economic Policy Symposium at Jackson Hole.

Dyson, B and G Hodgson (2016): "Digital cash: why central banks should start issuing electronic money", *Positive Money*.

Fung, B. and H. Halaburda (2016): "Central Bank Digital Currencies: A Framework for Assessing Why and How." *Bank of Canada Staff Discussion Paper No. 2016-22*.

Goodfriend, M (2016): "The case for unencumbering interest rate policy at the zero bound", paper presented at the Economic Policy Symposium at Jackson Hole.

Green, E (2008): "Some challenges for research in payment systems" in *The Future of Payment Systems*, eds A Haldane, S Millards and V Saporta, Routhledge, Milton Park.

Greenwood, R, S Hanson, J Rudolph and L Summers (2014): "Government debt management at the zero lower bound", Hutchins Centre on Fiscal & Monetary Policy at Brookings, *Working Papers*, no 5.

Greenwood, R, S Hanson and J Stein (2016): "The Federal Reserve's balance sheet as a financial-stability tool", paper presented at the Economic Policy Symposium at Jackson Hole.

Hayek, F (1945): "The use of knowledge in society", *American Economic Review*, vol 35, no 4, pp 519–30.

Kahn C and W Roberds (2009): "*Why pay? An introduction to payments economics*", Journal of Financial Intermediation 18(3), January, pp 1–23.

McAndrews, J (2017): "The case for cash", *ADBI working paper,* no 679.

Mersch, Y (2017a): "Digital base money: an assessment from the ECB's perspective", speech at the Bank of Finland, 16 January.

——— (2017b): "Why Europe still needs cash", Contribution for Project Syndicate.

Pfister, C (2017): "Monetary policy and digital currencies: much ado about nothing?" Bank of France, *Working Papers*, no 642.

Potter, S (2017): "Money markets at crossroads: policy implementation in times of structural change", remarks at the University of California, Los Angeles.

Pozsar, Z (2011): "Institutional cash pools and the Triffin dilemma of the US banking system", *IMF Working Papers*, no WP/11/90.

Reichsbank (1926): *Die Reichsbank, 1901–1925*, Druckerei der Reichsbank.

Rogoff, K (2016): *The curse of cash*, Princeton University Press.

Singh, M (2016): *Collateral and financial plumbing,* Risk Book, 2nd impression.

Skingsley, C (2016): "Should the Riksbank issue e-krona?", speech at FinTech Stockholm, 16 November.

Stein, J (2012): "Monetary policy as financial-stability regulation", *Quarterly Journal of Economics*, 127, February, pp 57–95.

Stevens, A (2017): "Digital currencies: threats and opportunities for monetary policy", National Bank of Belgium, *Economic Review*, June.

Sveriges Riksbank (2017): *The Riksbank's e-krona project – Report 1*, September.

Tobin, J (1985): "Financial innovation and deregulation in perspective", *Cowles Foundation Papers*, no 635.

Woodford, M (2000): "Monetary policy in a world without money," *International Finance*, vol 3, no 2, pp 229–60.

Annex A: Principles of monetary policy implementation

This Annex provides a short overview of the general principles of monetary policy implementation, namely the use of the central bank's balance sheet to achieve its operational target. This target, which can be controlled by the central bank on a day-to-day basis, is highly relevant to the fulfilment of its mandate (Bindseil (2014)).

Typically, central banks use an overnight rate as their operational target. The financial institutions that are directly relevant to this operational target and its transmission to money markets are the central bank's monetary counterparties. To achieve their operational target, central banks need to ensure that the value of attracting or trading away overnight funds from monetary counterparties equals the operational target. Two operational regimes are typically used for this purpose: a corridor and a floor system.

In a corridor system, central banks apply two interest rates to reserves: (i) up to a limited amount (depending on reserve requirements), the policy rate is applied; and beyond that (ii) a substantially lower deposit rate is paid.[31] Monetary counterparties may access an overnight lending facility at a higher rate. Central banks continuously need to ensure via open market operations (OMOs) that the overall amount of reserves equals the overall limit amount at which the policy rate applies. Central banks can increase flexibility in fulfilling this requirement by applying: (i) a band at which the policy rate applies instead of a limit; or (ii) the minimum required amount of reserves averaged over a maintenance period.

Central banks must forecast the demand for liquidity in order to be prepared to inject (or drain) the right quantity of reserves. This involves projecting day-to-day changes in autonomous factors – that is, all the balance sheet items outside of the direct control of the central bank's monetary policy implementation function that affect the amount of reserves.

The difference between the policy and the deposit rate provides an incentive for monetary counterparties to trade overnight funds among themselves, on a secured or unsecured basis. Abstracting from possible balance sheet and collateral costs, such transactions take place close to the policy rate. Thus, the policy rate becomes the marginal value of attracting or trading away overnight funds from monetary counterparties, while the overall amount of reserves can be relatively small. This enables central banks to run a relatively lean balance sheet. This means a balance sheet that is only slightly larger than banknotes outstanding, limiting the intermediary role of the central bank (Graph A1).

Under a floor system, central banks ensure that the marginal value of attracting or holding overnight funds from monetary counterparties equals the deposit rate. With substantial excess reserves, the marginal use for monetary counterparties of holding additional reserves is to earn the deposit rate (Graph A2). The deposit rate thereby becomes the de facto policy rate. To achieve this, monetary outright holdings must exceed the *original liquidity deficit*, ie the liquidity needs caused by net autonomous factors. Liquidity forecasting is less important because day-to-day fluctuations in the amount of reserves do not change the marginal value of attracting or holding overnight funds (with monetary counterparties).

In both operational regimes, flows into non-monetary deposits, that is digital central bank money held by non-monetary counterparties (eg the treasury, foreign central banks or FMIs) and banknotes result in a drain of reserves. In a corridor system, such flows need to be compensated by liquidity-injecting OMOs. In a floor system, such flows only need to be compensated if the liquidity surplus becomes insufficient and rates begin to rise above the deposit rate (monetary outright holdings threaten to fall below the original liquidity deficit). In practice, flows into banknotes are limited by the carrying cost of cash, making banknotes relatively inconvenient as a store of value. Flows into non-monetary deposits are typically limited by price

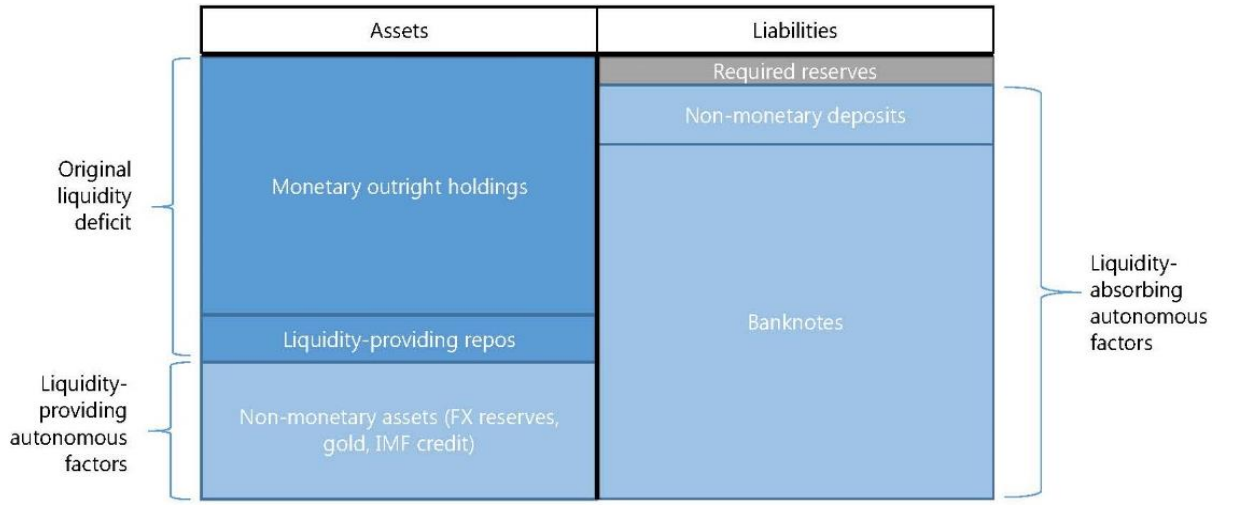
[31] Under zero reserve regimes, such as that of the Bank of Canada, the central bank charges a higher policy rate on negative balances (ie loans) and pays a lower deposit rate on positive balances. Under this system, required reserves are not necessary and the overall limit amount at which the policy rate applies can be zero.

disincentives beyond certain specified amounts, also making non-monetary deposits relatively unattractive as a store of value. Such price disincentives are often applied to limit the central bank's intermediary role. Different central banks put varying weights on this principle, however, and apply different price disincentives and access conditions to non-monetary deposits.

A stylised balance sheet of the central bank after the introduction of CBDC is depicted in Graph A3, reflecting the demand for CBDC and its increased assets holdings.

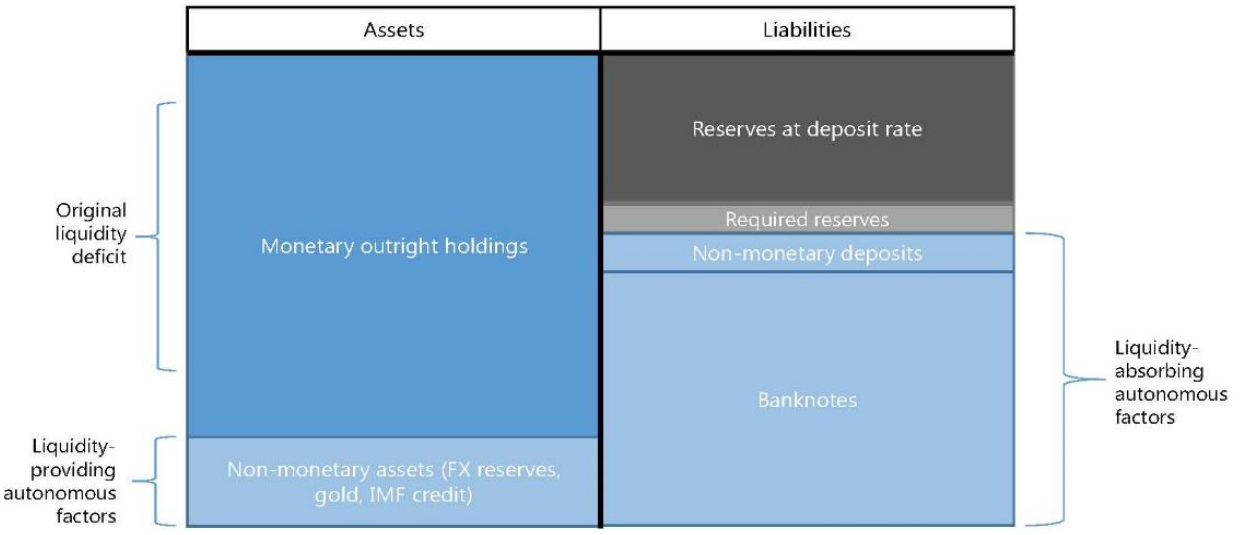
Corridor system without CBDC

Graph A1



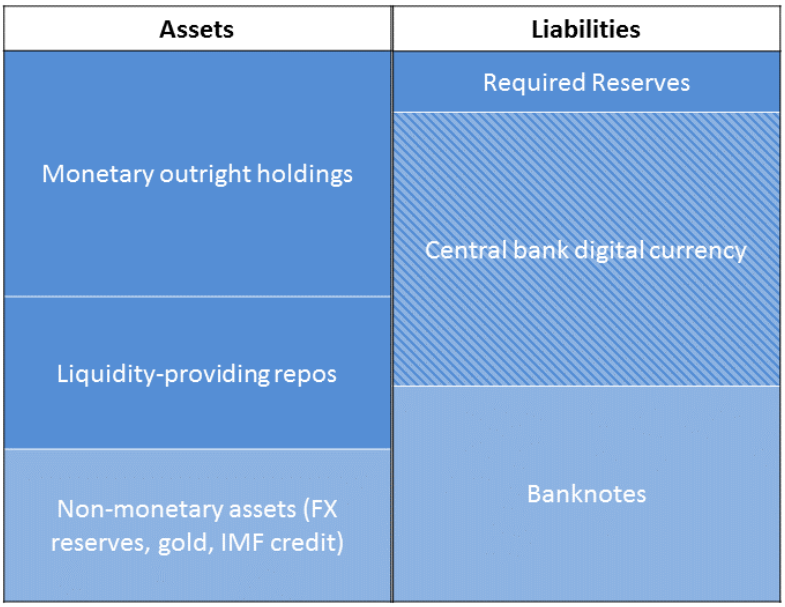
Floor system without CBDC

Graph A2



Central bank balance sheet with CBDC

Graph A3



Annex B: Flow-of-funds representation

A stylised flow-of-funds analysis illustrates qualitatively how sectoral balance sheets and the implementation and transmission of monetary policy may be affected by the introduction of a general purpose CBDC. The more CBDC is perceived by economic agents to be an attractive asset, the larger will be the substitution effects discussed below.

The balance sheets considered are those of:

i. *Households (retail)*. It is assumed that households hold real assets (RA), retail deposits at commercial banks (DEP) and banknotes (BAN). Furthermore, they invest in corporate/government and bank bonds (B + BB) and money market fund shares (FS) if their liquid funds exceed deposit guarantee schemes' coverage. They finance themselves through retail mortgage loans (RML) provided by commercial banks and their own funds or equity (E).

ii. *Corporations/government*. It is assumed that corporations and the government fund themselves via bank loans (L) and bonds (B) as well as money market instruments (MM). This sector holds real assets (eg public infrastructure, corporate facilities) and liquidity buffers in the form of cash pool participations (CPP).

iii. *Banks (monetary counterparties)*. Funding takes place by accepting retail deposits, by issuing money market instruments (eg secured funding via repos or unsecured funding via commercial paper) and bank bonds and by drawing on central bank credit facilities. These instruments fund purchases of government and corporate bonds, loans to corporates, retail mortgages to households and holdings of central bank reserves (RES).

iv. *The central bank*. The liability side of the central bank's balance sheet consists of banknotes held by households and reserve balances held by banks. On the asset side, the central bank has outright holdings of corporate, government and (covered) bank bonds and provides credit to banks, therewith implementing monetary policy.

The introduction of CBDC opens up a number of channels that affect patterns of financial intermediation in the economy (see the bold, red font balance sheet items in Table B1).[32] First, households may substitute banknotes for CBDC (**CBDCa**), which prompts a change on the central bank's liability side. Second, households may substitute retail deposits for CBDC (**CBDCb**) by making payments from retail deposits to CBDC accounts. To effect such payments, banks request the central bank to debit reserves held by them and credit the CBDC accounts. In order to ensure that reserves stay at the required level to implement monetary policy, the central bank buys bonds or provides additional credit to banks.[33]

The main question is how large these flows are likely to be and how financial market participants that attract or lose funding will adjust their behaviour. What assets will the central bank hold against the CBDC inflows? Will the financial market participants that lose funding raise funds elsewhere or will they deleverage?

Table B1 shows qualitatively one of the many possible outcomes. The central bank accommodates CBDC inflows by increasing its lending to monetary counterparties and outright holdings of bonds. The banks use the central bank's funds to compensate for the lost retail deposits (**CBDCb**). In this highly restrictive scenario, there is only a shift in intermediation and no impact on the real assets held by corporates/governments and households (ie no deleveraging and/or leveraging). Instead, the central bank intermediates between households, on the one hand, and banks and corporates/government, on the other.

[32] Further substitution effects could be induced as money market funds switch holdings of money market instruments (eg reverse, repos, commercial paper or treasury bills) for CBDC. These effects are omitted from the analysis for ease of exposition.

[33] Hence, it is assumed that the central bank either implements monetary policy through a corridor or a floor system with a minimum amount of excess liquidity, consistent with keeping short-term rates close to the deposit rate.

CBDC and the structure of the financial system: a flow-of-funds analysis[1] Table B1

Households (retail)			
Real assets	RA1	Equity	E
Retail deposits	DEP **– CBDCb**	Retail mortgage loans	RML
CBDC	**CBDCa + CBDCb**		
Banknotes	BAN **– CBDCa**		
Bonds (for investment)	B1 + BB1		
(Money market) fund shares	FS		
Corporations/government			
Real assets	RA2	Loans	L
Cash pool participation	CPP	Corporate/government bonds	B1 + B2 + B3
		MM instruments	MM1
Banks (monetary counterparties)			
Corporate/government bonds	B2	Retail deposits	DEP **– CBDCb**
Loans	L	MM instruments	MM2
Retail mortgage loans	RML	Bank bonds	BB1 + BB2
Reserves	RES	CB credit facilities	RES + BAN – B3 – BB2 **+ CBDCb**
Central bank			
CB credit facilities	RES + BAN – B3 – BB2 **+ CBDCb**	Reserves	RES
		Banknotes	BAN **– CBDCa**
Corporate/government/bank bonds	B3 + BB2	CBDC	**CBDCa + CBDCb**

[1] The analysis is performed under the assumption of a central bank operating through a corridor system.

Explanatory notes: CBDCa – amount of banknotes substituted for by households' CBDC holdings; CBDCb – amount of retail deposits at commercial banks substituted for by households' CBDC holdings; RA1 (RA2) – real assets held by households (corporates/government); MM1 (MM2) – money market instruments issued by corporates/government (banks); B1/B2/B3 – amount of bonds (either issued by corporates or government) held by households/banks/central bank; BB1 (BB2) – amount of bonds issued by banks and held by household (central bank).

In practice, however, some funding losses and gains and thereby some degree of deleveraging and/or leveraging are likely to happen as central bank credit leads to bank asset encumbrance. This, in turn, is costly to banks and may induce them to reduce their loans and bond holdings. To the extent that the shift in the structure of financial intermediation provokes higher (lower) liquidity, term and credit-risk premia on the funding for households and corporates/government, their capacity to hold real assets may decrease (increase).

Annex C: The impact of CBDC on seigniorage

Seigniorage represents income earned by a central bank from issuing (non-interest-bearing) banknotes. In a two-tier banking system, income from issuing money (banknotes and deposits at commercial banks) partly accrues to commercial banks, giving way to a broader notion of seigniorage. The design features of CBDC (described in section 2.2) determine how much of this broad seigniorage value accrues to commercial banks and to the central bank. If CBDC emerges as an attractive asset, seigniorage may move from commercial banks to the central bank, as agents substitute commercial bank deposits by CBDC.

There are two channels through which broad seigniorage value may change due to CBDC. First, CBDC affects the overall value of the money issuing function to the extent that CBDC reduces operational costs (eg costs related to printing, storage and transportation of banknotes, and settlement costs) and, especially at the outset, entails significant fixed infrastructure costs (but very low marginal costs). Second, as an additional and possibly attractive asset, CBDC may serve as a substitute for other non-deposit financial assets (eg shares in money market mutual funds). This latter effect would increase money in circulation and thereby broaden the overall seigniorage base.

Seigniorage accruing to the central bank depends on two key variables: the stock of currency in circulation and the difference in returns between central bank assets and currency liabilities. Introducing CBDC could change both factors. First, any CBDC-driven expansion of the balance sheet has a positive effect because most the funding cost equals the policy rate (ie the risk-free rate). Any asset that the central bank may buy from, lend to, or accept as collateral from its monetary counterparties should have an expected yield above the expected risk-free rate over the investment horizon. As a CBDC-driven expansion of the balance sheet entails a corresponding decline of retail deposits and money market instruments, such increased central bank seigniorage corresponds to decreased seigniorage income at banks and money market issuers. This effect may, however, be offset to some degree if CBDC were to lead to reduced demand for banknotes, which are non-interest bearing. And the impact would depend on the remuneration of CBDC: the higher the remuneration, the greater the reduction in seigniorage income from banknote circulation.

These effects would produce gains and losses for central and commercial banks, as well as for non-banks, which, in turn, could influence their financial robustness and hence have systemic financial stability consequences. For central banks, any significant reduction of seigniorage would constrain their ability to recapitalise following financial losses, in the absence of other sources of income. The persistence of low or even negative capital could put monetary policy and financial stability goals at risk.

Annex D: Members of the working groups

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Chair	Klaus Löber (European Central Bank)
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National Bank of Belgium	Filip Caron
Central Bank of Brazil	Daniel Gersten Reiss
Bank of Canada	Ben Fung
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Bank of Korea	Dong Sup Kim
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Netherlands Bank	Kirsten van Driel
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Saudi Arabian Monetary Authority	Mohsen Al Zahrani
Monetary Authority of Singapore	Tze Hon Lau
South African Reserve Bank	Arif Ismail
Sveriges Riksbank	Björn Segendorf
Swiss National Bank	Marco Cecchini and Nino Landerer
Bank of England	Simon Scorer
Board of Governors of the Federal Reserve System	David Mills and Brendan Malone
Federal Reserve Bank of New York	Vanessa Lee
Bank for International Settlements	Paul Wong (Secretary)
	Morten Bech and Stijn Claessens

Workstreams were led by Dirk Bullmann (European Central Bank), Shuji Kobayakawa (Bank of Japan), David Emery (Reserve Bank of Australia) and Brendan Malone (Board of Governors of the Federal Reserve System). Significant contributions were also made by Jiamin Lim (Reserve Bank of Australia); Hanna Halaburda (Bank of Canada); Thomas Leach (European Central Bank); Dion Reijnders (Netherlands Bank); Cordelia Kafetz (Bank of England); Jeff Marquardt and Sarah Wright (Board of Governors of the Federal Reserve System); Antoine Martin and Ray Fisher (Federal Reserve Bank of New York); and Ayse Sungur, Rebecca Chmielewski, Henry Holden, Rodney Garratt and Codruta Boar (Secretariat).

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Bank of Canada	Parnell Chu and Scott Hendry
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Hong Kong Monetary Authority	Nelson Chow
Reserve Bank of India	Senthil Kumar
Bank of Italy	Tommaso Perez
Bank of Korea	Dong Sup Kim
Netherlands Bank	Steef Akerboom and Dion Reijnders
Monetary Authority of Singapore	Jeremy Hor
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