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Future of Money

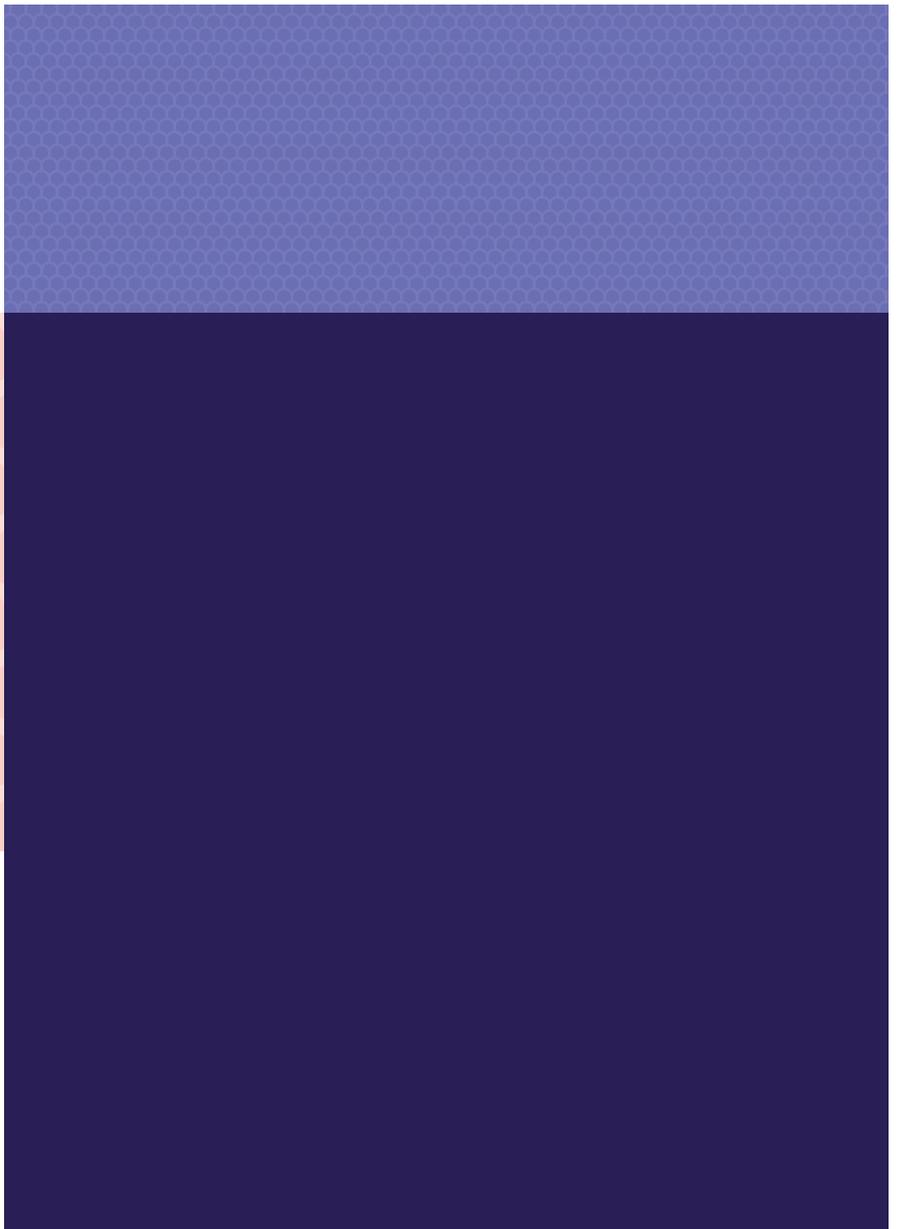
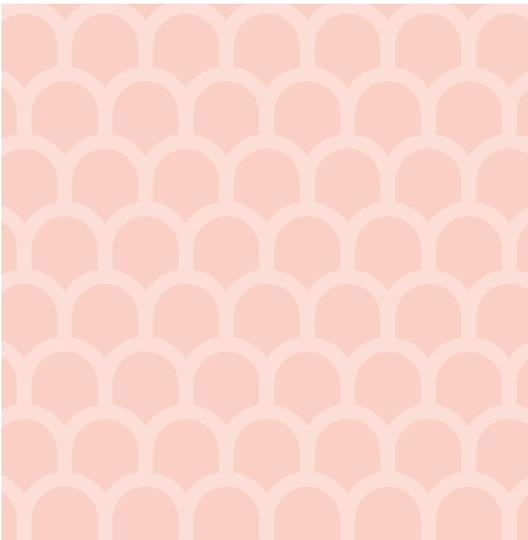


Discussion Paper

Central Bank Digital Currency

Opportunities, challenges and design

March 2020





BANK OF ENGLAND

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Foreword

For over 325 years, the Bank of England has provided safe money and a risk-free means of payment to households, businesses and the wider financial system. This is one of the key ways in which we fulfil our mission — given to us by Parliament — to promote the good of the people of the United Kingdom by maintaining monetary and financial stability.

The Bank has always innovated in the form of money and payment services that we provide, most recently by switching our banknotes from paper to safer and stronger polymer notes, and investing heavily in rebuilding our wholesale Real-Time Gross Settlement (RTGS) payment service, which provides high-value and time-critical payment services to financial institutions, and ultimately serves as the backbone for every electronic payment in the UK. We are also supporting a number of private-sector initiatives to improve the existing payments landscape.

It is now time to look further ahead, and consider what kind of money and payments will be needed to meet the needs of an increasingly digital economy. We are in the middle of a revolution in payments. Banknotes — the Bank's most accessible form of money — are being used less frequently to make payments. At the same time, fintech firms have begun to alter the market by offering new forms of money and new ways to pay with it.

These developments create major new opportunities, present some new risks, and raise a number of profound questions for the Bank. This paper considers one of the most important of these questions: as the issuer of the safest and most trusted form of money in the economy, should we innovate to provide the public with electronic money — or Central Bank Digital Currency (CBDC) — as a complement to physical banknotes?

A CBDC could provide households and businesses with a new form of central bank money and a new way to make payments. It could ensure that the public has continued access to a risk-free form of money issued by the central bank, which may be especially important in the future as cash use declines and new forms of privately issued money become more widely used in payments. CBDC could also be designed in a way that contributes to a more resilient, innovative and competitive payment system for UK households and businesses.

While CBDC poses a number of opportunities, it could raise significant challenges for maintaining monetary and financial stability. CBDC therefore has relevance to almost everything the Bank does, and would need to be very carefully designed if it were to be introduced.

The Bank has not yet made a decision on whether to introduce CBDC. We need to consider the questions carefully and in good time, alongside Her Majesty's Government. This paper is intended to be the basis for further research and dialogue between the Bank and the payments industry, technology providers, payments users, financial institutions, academics, other central banks, and public authorities. I encourage anyone with an interest on these fundamental issues to respond to the Bank on the potential benefits, risks, and practicality of CBDC.



Mark Carney
Governor

Executive summary

The Bank of England's objectives, as set by Parliament, are to maintain monetary and financial stability. To support these objectives, the Bank provides the safest and most trusted form of money to households, businesses and the financial system. But the way we pay is changing, with use of banknotes falling, and the use of privately issued money and alternative payment methods rising. In this context, the Bank is exploring the concept of Central Bank Digital Currency (CBDC), as are central banks across the world.⁽¹⁾

A Central Bank Digital Currency would be an innovation in both the form of money provided to the public and the payments infrastructure on which payments can be made. At the moment, the public can only hold money issued by the Bank in the form of banknotes. Only commercial banks and certain financial institutions⁽²⁾ can hold *electronic* central bank money, in the form of 'reserves' held in the Bank's Real-Time Gross Settlement (RTGS) service. Unlike banknotes, CBDC would be electronic, and unlike reserves, CBDC would be available to households and businesses. CBDC would therefore allow households and businesses to directly make payments and store value using an electronic form of central bank money. For this reason, CBDC is sometimes thought of as equivalent to a digital banknote, although in practice it may have other features depending on its final design.

If a CBDC were to be introduced in the UK, it would be denominated in pounds sterling, so £10 of CBDC would always be worth the same as a £10 banknote. Any CBDC would be introduced alongside — rather than replacing — cash and commercial bank deposits.

The Bank has not yet made a decision on whether to introduce CBDC, and intends to engage widely on the benefits, risks and practicalities of doing so. This discussion paper is part of that process.

CBDC could present a number of opportunities for the way that the Bank of England achieves its objectives of maintaining monetary and financial stability. It could support a more resilient payments landscape. It also has the potential to allow households and businesses to make fast, efficient and reliable payments, and to benefit from an innovative, competitive and inclusive payment system. It could help to meet future payments needs in a digital economy by enabling the private sector to create services that support greater choice for consumers. It could build on our ambitious renewal of the RTGS service and complement private sector initiatives to improve payments.

CBDC may also provide safer payment services than new forms of privately issued money-like instruments, such as stablecoins. Ensuring that the public has continued access to a risk-free form of money issued by the Bank may be especially important in the future, and help to address some of the consequences of a decline in the use of physical cash. Finally, a domestic CBDC might be an enabler of better cross-border payments in the future.

CBDC would also introduce important policy challenges and risks that need to be carefully considered and managed. If significant deposit balances are moved from commercial banks into CBDC, it could have implications for the balance sheets of commercial banks and the Bank of England, the amount of credit provided by banks to the wider economy, and how the Bank implements monetary policy and supports financial stability. Nonetheless, CBDC can be designed in ways that would help mitigate these risks.

This paper outlines an illustrative 'platform' model of CBDC designed to enable households and businesses to make payments and store value. This is not a blueprint for CBDC, nor does it approach a decision to introduce one. Rather, it is intended to illustrate the key issues as a basis for further discussion and exploration of the

(1) [Central Bank group to assess potential cases for central bank digital currencies](#), Bank of England Press release, January 2020.

(2) Reserves can be held at the Bank of England by banks, building societies, PRA-supervised broker-dealers, and central counterparties (CCPs). In addition, some non-bank Payment Service Providers and other Financial Market Infrastructures hold settlement accounts at the Bank of England.

opportunities and challenges that CBDC could pose for payments, the Bank's objectives for monetary and financial stability, and the wider economy.

In the 'platform' model, the Bank of England would provide a fast, highly secure and resilient technology infrastructure, which would sit alongside the Bank's RTGS service, and provide the minimum necessary functionality for CBDC payments. This could serve as the platform to which private sector *Payment Interface Providers* would connect in order to provide customer-facing CBDC payment services. Payment Interface Providers could also build 'overlay services' — additional functionality that is not part of the Bank's core infrastructure, but which might be provided as a value-added service for some or all of their users. As well as providing more advanced functionality, these services might meet future payment needs by enabling programmable money, smart contracts and micropayments. Payment Interface Providers would be subject to appropriate regulation and supervision in line with any risks they might pose.

Choices around technology would have a major impact on the extent to which CBDC meets our overall objectives. Although CBDC is often associated with Distributed Ledger Technology (DLT), we do not presume any CBDC must be built using DLT, and there is no inherent reason it could not be built using more conventional centralised technology. However, DLT does include some potentially useful innovations, which may be helpful when considering the design of CBDC. For example, elements of decentralisation might enhance resilience and availability, and the use of smart contract technology may enable the development of programmable money. However, adoption of these features would also come with challenges and trade-offs that must be carefully considered.

The purpose of this discussion paper is to begin a dialogue on the appropriate design of CBDC and an evaluation of whether the benefits of CBDC outweigh the risks. **Given the wide-ranging implications of CBDC for the Bank's objectives and the wider economy, any eventual decision to introduce a CBDC would involve Her Majesty's Government, Parliament and regulatory authorities, and engagement with society more generally.** We invite feedback and ideas from the public, technology providers, the payments industry, financial institutions, academics and other central banks and public authorities, and have outlined our key questions for further research in the final chapter.

How to respond

Written responses to any of the questions outlined in Chapter 7, or any other relevant observations, are requested by 12 June 2020.

Please address any comments or enquiries to:

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1 Our approach to CBDC

Key points

- At the moment, the public can hold central bank money in the form of banknotes, but only banks and certain other financial institutions can hold electronic central bank money, in the form of central bank reserves. A Central Bank Digital Currency (CBDC) would be an electronic form of central bank money that could be more widely used by households and businesses to make payments and store value. CBDC is sometimes thought of as equivalent to a digital banknote, although in practice it may have other features that will depend on its final design.
- The Bank of England's primary objectives are to maintain monetary and financial stability. CBDC should be designed in a way that supports those objectives.
- To develop the illustrative model of CBDC presented in Chapter 4, we have thought through its economic characteristics (as a new form of central bank money), the functionality and technology used to power a CBDC payment system, and the possible roles of the central bank and private sector in providing parts of the CBDC ecosystem.
- CBDC would provide both a new form of central bank money, and a new payments infrastructure. So it is important to consider how CBDC fits into the wider payments landscape, and how it interacts with and complements other initiatives to improve payments.

1.1 What is CBDC?

At the moment, the public can hold money issued by the Bank of England ('central bank money') in the form of banknotes, but only banks and certain other financial institutions⁽¹⁾ can hold electronic central bank money, in the form of 'reserves' (Figure 1.1). A Central Bank Digital Currency (CBDC) would be an electronic form of central bank money that could be used by households and businesses to make payments and store value. This wider access to central bank money could create new opportunities for payments and the way the Bank maintains monetary and financial stability.

Earlier research has explored how CBDC could provide improved settlement and payments in financial markets — this is known as 'wholesale CBDC'.⁽²⁾⁽³⁾ However, in this paper we focus exclusively on 'retail CBDC' which would be designed to meet the payments needs of households and businesses outside the financial sector. A retail CBDC

(1) Reserves can be held at the Bank of England by banks, building societies, PRA-supervised broker-dealers and Central Counterparties (CCPs). In addition, some non-bank Payment Service Providers and other Financial Market Infrastructures hold settlement accounts at the Bank of England. For further detail see www.bankofengland.co.uk/markets/bank-of-england-market-operations-guide.

(2) Payments can be broadly split into 'retail' versus 'wholesale', and domestic versus cross-border. 'Retail' in a payments context refers to all payments that involve households and/or small or medium-sized businesses (not just those in a 'retail' or e-commerce context). Wholesale payments are those made between financial institutions (eg banks, pension funds, insurance companies) and/or large (often multinational) corporations. (Financial institutions can also make 'retail' payments to households and businesses, for example collecting insurance premiums or paying staff.) However, there is no legal distinction between wholesale and retail payments.

(3) As explored by, for example Project Jasper-Ubin (Monetary Authority of Singapore, Bank of Canada and J.P. Morgan (2019)). See also OMFIF and IBM (2018).

Figure 1.1 Stylised continuum of access to electronic central bank money^(a)

(a) Subject to meeting certain criteria — see footnote (1) on page 7.

would be a new form of money that would exist alongside cash and bank deposits (see Box 1), rather than replacing them. A CBDC would be denominated in pounds sterling, just like banknotes, so £10 of CBDC would always be worth the same as a £10 note. CBDC is sometimes thought of as equivalent to a digital banknote, although in practice it may have other features that will depend on its final design.

CBDC would require the creation of *infrastructure* so that it can be used to make payments. This infrastructure includes everything from the database on which CBDC is recorded, through to the applications and point-of-sale devices that are used to initiate payments. CBDC would offer users another way to pay, which might ultimately be faster and more efficient, with new functionality added over time.

Although the term CBDC includes the words 'digital currency', CBDC would be something fundamentally different to 'cryptocurrencies' (or 'cryptoassets'), such as Bitcoin. Many cryptoassets are privately issued and not backed by any central party. They are not considered a currency or money because they do not perform the essential functions of money (see Box 1): they are too volatile to be a reliable store of value, they are not widely accepted as a means of exchange, and they are not used as a unit of account (Carney (2018)). Some privately issued cryptoassets, known as 'stablecoins', aim to overcome these shortcomings and provide stability of value via some form of backing. Depending on the nature of assets backing the 'coin', and how they are held, the stablecoin may be unable to provide stability of value and may come with other risks (as discussed in Chapter 2.4). In contrast, a UK CBDC would be a new risk-free form of (digital) pound sterling, issued by the central bank, and would therefore perform all the essential functions of money.

However, the technological innovations that made cryptoassets possible have evolved into a broad group of technologies often referred to as Distributed Ledger Technology (DLT). While we do not presume CBDC must be built using DLT (and there is no reason CBDC could not be built using centralised technology), some of the individual component innovations of DLT may be useful when applied to CBDC (these are discussed in Chapter 6).

1.2 Our approach to designing CBDC

This paper uses the following approach to structure our thinking and design principles around CBDC. In Chapter 4 we present an illustrative model of CBDC that draws on earlier research by staff at the Bank of England⁽⁴⁾ and other central banks. This model is intended as a basis for further discussion and research, to illustrate the choices and the impacts, rather than a blueprint for a design. More detailed analysis would be required before the Bank could make a confident decision on whether to introduce CBDC, and if so, in what form.

Step 1: Understand the opportunities and challenges of CBDC: We need to develop a clear understanding of the opportunities that the introduction of CBDC could pose, and the challenges that would need to be managed (see Chapter 2).

Step 2: Set an overall objective that any design of CBDC would need to meet: This overall objective should follow from the Bank's objectives and mandate, taking into account other public policy objectives, and will inform the **design principles** around which CBDC should be designed. Based on the Bank of England's objectives to maintain monetary and financial stability, we consider it essential that any CBDC must meet the design principles of being reliable and resilient, fast and efficient, and open to innovation and competition (see Chapter 3).

(4) For example, see Broadbent (2016), Barrdear and Kumhof (2016), Meaning *et al* (2018), and Kumhof and Noone (2018).

Box 1

How does CBDC compare to other forms of money?

This box discusses the different types of central bank and commercial bank money that are in use today, and how CBDC would compare.

Functions of money

As discussed in McLeay, Radia and Thomas (2014a) money is fundamentally a special kind of IOU (or promise to pay) that performs certain key roles in society, serving as (a) **a store of value** with which to transfer purchasing power from today to the future; (b) **a medium of exchange** with which to make payments for goods and services, and (c) **a unit of account** with which to measure the value of a particular good, service, savings product or loan. These roles function as a hierarchy and reveal that money is, in essence, a social convention (Carney (2018)).

Money must be a reasonable store of value — it should not lose value substantially in the time between receiving and making payments. There are many assets that act to some degree as stores of value, such as houses, but which are not used as a medium of exchange. An asset can only act as a medium of exchange if at least two people are prepared to treat it as a store of value, at least temporarily. It is also generally more efficient if the medium of exchange in an economy becomes its unit of account — the unit in which goods and services are priced and debts are denominated. This helps the holders of money assess how many goods and services their money can buy at any point and may make it more acceptable to others as a means of payment.⁽¹⁾

Current forms of money

There are three forms of money that are widely in use and form the core of the UK monetary system. Each of these are denominated in the pound sterling, which is the unit of account of the United Kingdom.

(1) Banknotes: The vast majority of physical currency used in the UK economy is central bank money — banknotes issued by the Bank of England.⁽²⁾ Most of those notes are held by households and businesses as a means of payment or store of value. But commercial banks also hold some banknotes at their counters and cash machines in order to meet deposit withdrawals. This is to ensure customers can easily convert their bank deposits into central bank money.

As stated in their inscription, banknotes are a 'promise to pay' the holder of the note, on demand, a specified sum in terms of the unit of account (for example £5). The Bank of England must ensure that the value of goods and services in terms of the sterling unit of account remains stable in order to retain trust in Bank of England notes and the sterling payment system more generally.

(2) Bank Deposits: In today's economy most of the money used by households and businesses is commercial bank money — electronic bank deposit accounts. Deposits are created when banks issue loans McLeay, Radia and Thomas (2014b). Commercial bank deposits are at the heart of the UK monetary system and account for around 97% of the money held by households and businesses. They are a liability of the banking system — banks stand ready to convert those deposits into central bank money in the form of physical cash or to honour payments customers make with those deposits, which will typically involve a transfer of money to a customer in another bank.⁽³⁾ So unlike central bank money in the form of banknotes, commercial bank money in the form of deposits is not without credit risk. A customer needing to make a payment relies on their bank to have sufficient assets to enable a cash withdrawal or enable settlement with another bank. An insolvent bank with insufficient assets will not be able to honour such commitments. In order to minimise these risks, household deposits up to an amount

(1) If UK shops priced items in US dollars, while still accepting payment only in sterling, customers would have to know the sterling-dollar exchange rate every time they wanted to buy something which would require time and effort on the part of the customers. See also Brunner and Meltzer (1971).

(2) Banknotes make up 94% of physical currency, while coins make up just 6%. Of the banknotes that circulate in the UK economy, nearly 10% are issued by Scottish and Northern Irish commercial banks, but those banknotes themselves are backed by Bank of England notes, UK coins, and funds on deposit at the Bank of England (For further details see www.bankofengland.co.uk/banknotes/scottish-and-northern-ireland-banknotes). In many countries, coins are also issued by the central bank, but in the UK coins are produced by The Royal Mint, and are nominally a liability of the government (HM Treasury (2015)).

(3) A household paying for goods on a debit card from a shop is essentially instructing their bank to debit an amount from their account and pay it into the account held by the shop, which may be held at a different bank.

of £85,000 are protected under the Financial Services Compensation Scheme (FSCS). But large deposits in excess of this amount are not insured and subject to credit risk.

A distinction is often made between 'sight' deposits that are largely used for transactions purposes, typically associated with current (checking) accounts that can be accessed immediately, and 'time' deposits that are made for store of value or savings purposes which typically earn more interest if they are not accessed before a certain date or notice period.

(3) Central bank reserves (commercial banks' deposits at the central bank): Just as households and business hold deposits in accounts at commercial banks, those commercial banks themselves hold accounts at the Bank of England. The deposits in these accounts are known as central bank reserves, and are the asset used by banks when they need to make payments to each other. Like banknotes, reserves are central bank liabilities and are risk free. For this reason, reserves are the ultimate settlement asset used by the banking system.

Convertibility

The Bank of England also stands ready to swap reserves for banknotes should the commercial banks need it, for example to ensure there are banknotes in ATMs before Bank Holiday weekends (when demand for cash usually increases). So, underpinning the current sterling monetary system is the principle that both types of central bank money (reserves and banknotes) are directly convertible into one another, and that households and businesses can convert their deposits into central bank money, in the form of physical cash.

How CBDC compares

A CBDC could in principle perform many of the functions currently offered by both cash and bank deposits. However, to be practical and attractive, CBDC would need to be directly convertible into cash and deposits.

CBDC would be equally safe and free of credit risk as physical cash, but could be more convenient as a means of payment for both households and businesses, particularly for electronic and remote payments. So there may be some shift between cash and CBDC.

Compared to bank deposits held by households, which are insured up to £85,000 under the FSCS, a CBDC would be equally safe and have no credit risk, and similar usefulness as a means of payment to an ordinary current account. But it is not clear that households would necessarily want to substitute from deposits to CBDC given that deposits at a commercial bank offer customers other services, including credit facilities, which would not be offered under a CBDC. However, if firms providing CBDC-related payment services are able to bundle other useful services with a CBDC account, this may prove attractive to some deposit holders. The incentive to substitute away from bank deposits will also depend on whether the CBDC is remunerated or not (discussed in Chapter 5).

Compared to bank deposits that are not covered by the FSCS, CBDC could play a similar role as a means of payment but would have no credit risk. That may make it attractive to some businesses who typically hold unsecured deposits not covered by the FSCS. But again, holding an account at a commercial bank may offer non-financial businesses the use of credit facilities and other benefits that arise from having a long-standing relationship with that bank.

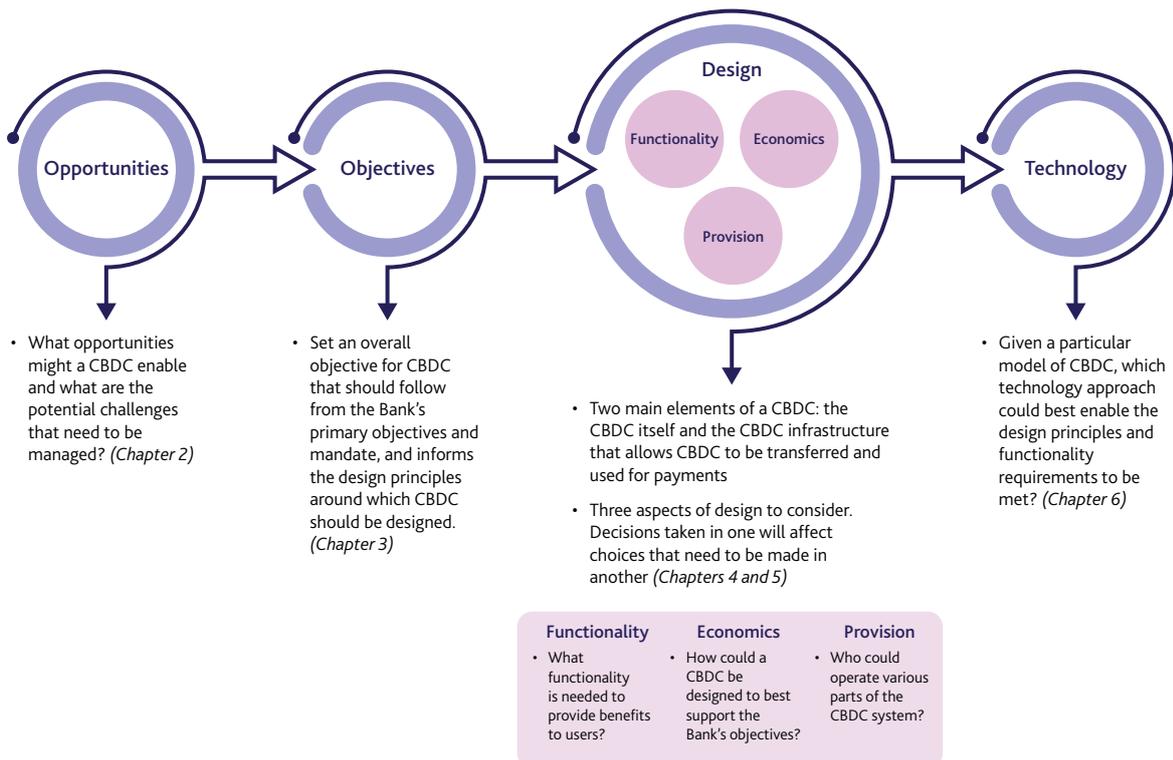
Overall, the introduction of CBDC will lead to some substitution away from existing forms of money. But the scale of substitution and the implications for monetary and financial stability will depend very much on functionality, remuneration and other design features (discussed in detail in Chapter 5).

Step 3: Design CBDC. There would be two main elements to any CBDC: (1) the CBDC itself (ie access to a new form of central bank money) and (2) the CBDC *infrastructure* that allows CBDC to be transferred and used for payments. There are three principal aspects of design to consider, and decisions taken in one area will affect choices that need to be made in other areas:

- (a) **Provision** concerns choices around *who would do what* in providing CBDC. The responsibilities and functions involved in providing CBDC could be allocated in different ways between the public sector (eg the Bank and other authorities) and the private sector (eg financial institutions, payment providers, fintechs and technology firms). Decisions around provision would have a significant impact on whether CBDC as a whole is resilient, open to competition, interoperable, and designed around the comparative advantages of the private and public sector. There are also significant trade-offs to consider (see Chapter 4.)
- (b) **Functional design** is about ensuring that the payments function of CBDC provides a clear benefit and utility for users. It concerns the types of payments that could be made using CBDC, how users would interact with CBDC, and whether the functionality of CBDC could be extended if payments needs were to change in future. Decisions taken here would have a particular impact on whether CBDC is user-friendly and widely accessible, and on the level of privacy in the system (see Chapter 4).
- (c) **Economic design** concerns aspects such as access (who could hold CBDC?), remuneration (should CBDC bear interest?), limits (should there be limits on the amount of CBDC that can be held?), and convertibility (should CBDC be freely convertible for other forms of central bank money, and for bank deposits?). These choices would be particularly important in influencing how CBDC supported the Bank’s ability to achieve its mission of maintaining monetary and financial stability, and the impact a CBDC would have on other forms of payment and payment systems, and the banking sector (see Chapter 5.)

Step 4: Technology: Given a particular model of CBDC, it is important to assess which technology could best enable the design principles and functionality requirements to be met. We must also think about the technological trade-offs involved between different design principles. Decisions taken here have a particular effect on the extent to which CBDC could be resilient, secure, fast, efficient, extensible, available and scalable (see Chapter 6). These steps are summarised in **Figure 1.2**.

Figure 1.2 Our approach



1.3 CBDC and the wider payments landscape

CBDC would provide households and businesses with both a new form of money and a new way of making payments, which could exist alongside other forms of money and payment systems, such as physical cash and bank deposits. It is therefore crucial to consider how CBDC might fit into the wider payments landscape, both today and in the future, and whether it could offer additional benefits that might not be offered by other payment systems or services.

There are many current initiatives to improve payments in the UK and internationally, a number of them being led or overseen by the Bank. Important initiatives include the Bank's own programme to renew its Real-Time Gross Settlement (RTGS) service. This renewal programme will deliver a world-leading service which is fit for the future, through increasing resilience and access, offering wider interoperability, improved user functionality, and strengthened end-to-end risk management of the UK's High-Value Payment System. As part of this initiative the Bank recently expanded access to settlement accounts to non-bank payment service providers and is currently considering whether to provide these firms with the ability to hold deposits at the Bank overnight. The Bank is also part of the Joint Authorities Cash Strategy Group, which seeks to ensure cash will continue to be accessible, and is contributing to HM Treasury's review of challenges and opportunities from innovation in the payments landscape. Finally, the planned development, by Pay.UK, of the New Payments Architecture for UK retail payments, aims to further enhance the resilience and speed of UK payments. These initiatives are described in detail in the appendix.

The Bank will continue to support these initiatives, recognising the significant benefits they should provide for UK payments. Our work on CBDC aims to help us understand whether, and how, CBDC could interact with RTGS renewal and these initiatives, and whether CBDC could provide additional benefits, contributing to a diverse and resilient payment system. As part of this ongoing analysis, the Bank will also consider if the benefits offered by CBDC could be achieved in other ways, for example by changing policies to support innovation in existing payments systems or to address market failures. In addition, some issues in payments might also be the result of co-ordination problems, where the Bank can play a role in resolving coordination failures rather than building new infrastructure itself.

2 Opportunities for CBDC to support the Bank's objectives

Key points

- CBDC offers a number of opportunities for the way that the Bank of England achieves its objectives of maintaining monetary and financial stability.
- CBDC could increase the availability and usability of central bank money, helping to support monetary policy and financial stability, and could help to avoid the risks of new forms of private money creation, such as stablecoins. It could support a resilient, innovative and competitive payments landscape, helping to meet future payments needs. It could also help to address the consequences of a decline in the use of cash.⁽¹⁾ Finally, a domestic CBDC could be a means to deliver better cross-border payments in the future.
- Each of these opportunities also comes with implications and challenges that would need to be carefully considered. Depending on its design, CBDC could impact the structure of the banking system (as discussed in detail in Chapter 5) and the way that the Bank achieves its objectives.

2.1 Overview

As set by Parliament, the Bank of England's objectives are to maintain monetary and financial stability. CBDC would be an innovation in both the form of money provided to the public, and the payments infrastructure on which payments can be made, and so could have wide-ranging opportunities and implications for both monetary and financial stability. The Bank therefore needs to consider both the opportunities and challenges that CBDC presents for the way we achieve our objectives.⁽²⁾

This chapter considers seven ways in which CBDC could support the Bank's objectives to maintain monetary and financial stability, through the provision of a new form of money and a new payments infrastructure:

- Supporting a resilient payments landscape.
- Avoiding the risks of new forms of private money creation.
- Supporting competition, efficiency and innovation in payments.
- Meeting future payment needs in a digital economy.
- Improving the availability and usability of central bank money.
- Addressing the consequences of a decline in cash.
- As an enabler for better cross-border payments.

These opportunities may also support the government's wider economic policy.

(1) By cash we mean physical banknotes (issued by the central bank) and coins. In the UK coins are issued by the Royal Mint on behalf of HM Treasury, and so are not technically central bank money. In most countries, both coins and banknotes are issued by the central bank.

(2) Motivations for CBDC vary depending on the different conditions in different countries; we have focused on the UK context while recognising that other authorities may be pursuing slightly different goals through their CBDC programmes.

2.2 How the Bank currently achieves its objectives

As described in Chapter 1.1, the Bank of England issues the safest and most trusted forms of money in the UK:

- Commercial banks and selected financial institutions hold electronic central bank money in their accounts in the Real-Time Gross Settlement (RTGS) service at the Bank. These balances are known as ‘reserves’ or ‘settlement’ balances. Reserves are used to implement monetary policy, and to move money in real time between financial institutions, delivering final and risk-free settlement. This RTGS service forms the backbone of every electronic payment in the UK.
- The Bank provides banknotes to households and businesses for use as a means of payment and store of value that is free of credit risk. Banknotes can provide an anchor of confidence in the banking system, as households and businesses know that they can convert deposits to central bank money, supporting financial stability.⁽³⁾

We use reserves to implement monetary policy, supporting monetary stability. We vary the interest rate paid on reserves to influence the interest rates offered and charged by banks, which has an effect on spending and inflation in the economy. This helps to keep the value of money broadly stable in terms of the amount of goods and services it can buy. Reserves also help us meet our financial stability objective, by allowing us to provide the highest quality liquidity to the financial system, in good times and in bad. This liquidity helps firms to settle payments in a timely manner, and to guard against unexpected liquidity demands.

In providing electronic money to banks and selected financial institutions, and banknotes to the public, the Bank supports all types of payments in the economy. This ensures that we have stable and resilient payment systems and underpins the Bank of England’s primary objectives for monetary and financial stability.

However, by volume, the majority of payments made today by households and businesses are not made in cash or reserves, but by transfers of bank deposits through retail interbank payment systems and card networks. Disruption to payment systems can pose risks to financial stability, and so the Bank has responsibility for ensuring that systemically important payment systems are stable and resilient, and that people and businesses can make the critical payments upon which they rely. This is why the Bank’s Financial Policy Committee (FPC) — the body charged with safeguarding financial stability in the United Kingdom — considers the provision of payment and settlement services as one of the vital functions that the financial system as a whole performs in our economy.⁽⁴⁾ Furthermore, the Bank is responsible for protecting and enhancing the stability of the financial system, including banks. This secures the monetary stability of deposits *vis-à-vis* central bank money.

The Bank is also committed to supporting wider innovation and improvements in payments. One reason for this is that better payments can boost economic activity,⁽⁵⁾ supporting the government’s wider economic objectives.

2.3 The changing payments landscape

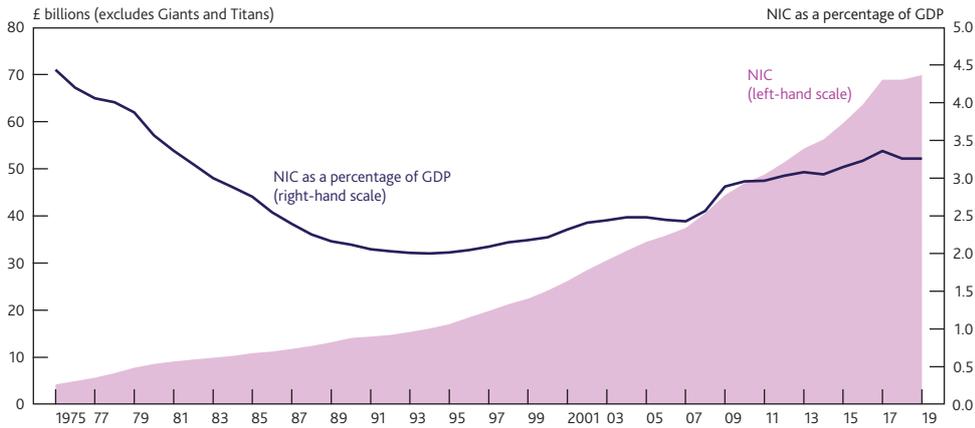
The way we pay is changing. For over 300 years, banknotes have been the only way in which households and non-bank businesses can directly use central bank money to make payments. However, although the total value of banknotes in the economy remains near an all-time high (**Chart 2.1**), people are making fewer payments in cash. Whereas 60% of payments (by volume) were made using banknotes in 2008, this fell to 28% of payments by 2018 (**Chart 2.2**), and is predicted to fall to just 9% of payments by 2028 (UK Finance, (2019)). Countries like Sweden and Norway are further along in this trend: in Sweden, over half of retailers expect to stop accepting cash payments by 2025 (Erlandsson and Guibourg (2018)).

(3) This is a motivating factor for the Riksbank’s e-krona project (Sveriges Riksbank (2018)).

(4) The FPC’s response to HM Treasury’s annual remit letter states ‘the purpose of preserving stability is to contribute to avoiding serious interruptions in the vital functions which the financial system as a whole performs in our economy: notably, the provision of payment and settlement services...’.

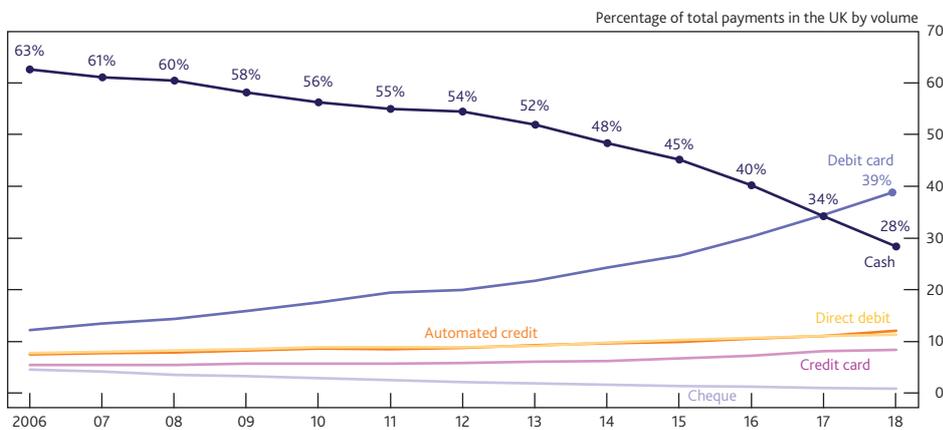
(5) See, for example, Hasan, De Renzis and Schmiedel (2013).

Chart 2.1 UK notes in circulation (NIC)



Source: Bank of England.

Chart 2.2 Decline of cash as a means of payment



Source: UK Finance 2019.

This decline in the use of cash as a means of payment means that the majority of payments in the UK are now made by transfers of bank deposits through retail payment systems, such as Faster Payments, Bacs, Cheque Imaging, and credit or debit cards. Most payments that were previously made in cash are now made by card (debit and credit); nearly half of all payments were made with credit and debit cards in 2018 (UK Finance (2019)).

New forms of money and payments are also emerging, such as stablecoins (cryptoassets⁽⁶⁾ whose value is linked to another asset). Whereas existing payment systems transfer value that is created by other entities — central banks or commercial banks — stablecoins propose to create the digital tokens which aim to represent and store value, as well as the platform on which those tokens can be transferred. As discussed below, this creation of money-like instruments poses potential risks that go beyond those usually associated with existing payment systems (Bank of England (2019b)).

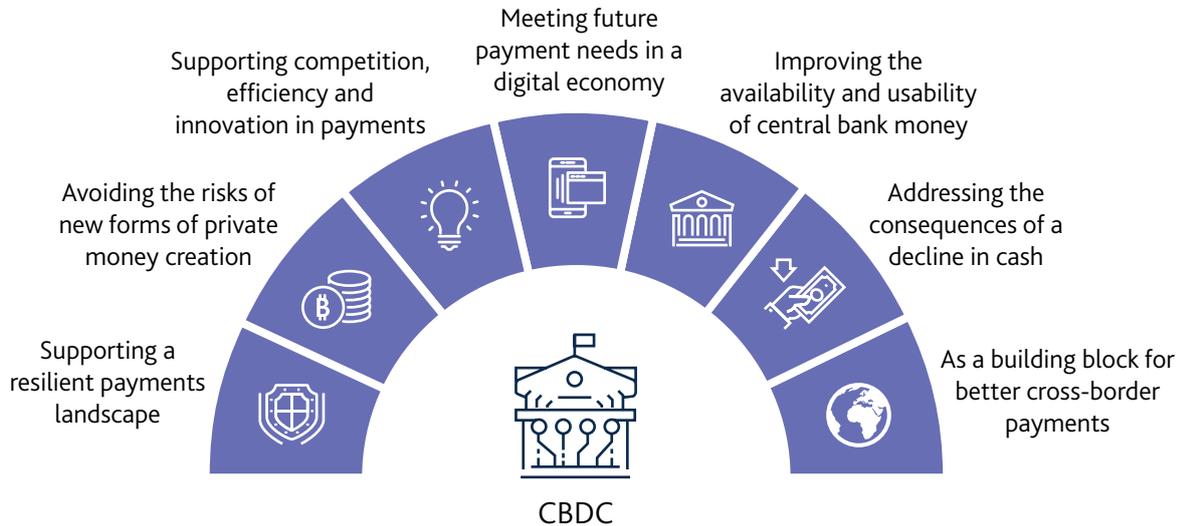
The changing nature of money and payments is critical to the Bank. Central bank money in the form of banknotes and reserves are central to our ability to achieve monetary and financial stability today. Therefore, as people’s use of money and payments evolves, and different forms of privately issued money increasingly dominate the payments landscape, it is appropriate for the Bank (along with other central banks) to consider whether it should issue a new form of central bank money to households and businesses. CBDC, as a new form of publicly issued central bank money, could complement privately issued money and could enhance the Bank’s ability to achieve its objectives in the future.

(6) The Financial Stability Board (FSB) defines cryptoassets as ‘a type of private asset that depends primarily on cryptography and distributed ledger or similar technology as part of their perceived or inherent value’.

2.4 Opportunities for CBDC to support monetary and financial stability

There are a number of ways in which CBDC could support the Bank's objectives to maintain monetary and financial stability, through the provision of a new form of money and a new payments infrastructure. These are summarised in **Figure 2.1**.

Figure 2.1 Opportunities for CBDC to support monetary and financial stability



Supporting a resilient payment landscape

UK electronic payment systems are already highly resilient and secure. However, the continued shift from cash to electronic payments increases the reliance on electronic payment systems, which has implications for the diversity and resilience of the payments landscape. Cards and cash are typically the only two options for point-of-sale transactions, with cards usually the only option for e-commerce.⁽⁷⁾ Consequently, the operational resilience of the cards network is increasingly critical, and this increasing reliance on a single electronic payment method could reduce the resilience of the payments landscape.

Cash currently provides a useful contingency to electronic payment systems in the event there is disruption to card payment networks. However, as the use of cash in payments declines, the ability to use it as a contingency payment system will also decline.

CBDC could therefore enhance financial stability by contributing to resilience in payments and providing some core payment services outside of the commercial banking system. By providing a new way to make payments, it could diversify the range of payment options, particularly for e-commerce (where cash cannot be used). It is less likely that both card networks and a CBDC network would suffer outages at the same time, and so CBDC could serve as a substitute. CBDC must be designed from the ground up to be as resilient as possible, for example this might include applying some aspects of decentralisation (discussed in Chapter 6.3) to enhance operational resilience, and avoiding reliance on legacy systems. The structure of the CBDC ecosystem could also be designed to avoid some of the vulnerabilities in payment systems that have evolved over time, complementing ongoing work to enhance resilience in existing payment systems. However, CBDC would still be vulnerable to a large-scale outage of electricity and data networks, unless some kind of offline payments functionality is developed (discussed in Chapter 4.3). In addition, CBDC would only serve as a useful contingency if, at the time of any outage, people already held CBDC and knew how to make CBDC payments, and it was widely accepted by merchants.

(7) Although the UK has Faster Payments which allows users to instantly transfer a deposit between the buyer and seller's bank accounts, there is no retail interface that allows this infrastructure to be used at the 'bricks and mortar' or online point of sale (unlike in other countries) that has any meaningful level of adoption by banks and merchants.

The introduction of CBDC would also pose some risks to payments. A very successful CBDC could displace existing payment systems and ultimately *reduce* diversity of payment options, creating a new form of concentration risk. The prospect of the introduction of CBDC could potentially discourage innovation in existing payment systems, potentially delaying other initiatives that could enhance resilience, speed and efficiency. These risks would need to be carefully managed.

Avoiding the risks of new forms of private money creation

Existing payment systems transfer money that has been created either by the Bank of England or by commercial banks (see Box 1). While the commercial bank money used in existing payment systems is not risk free — for example, commercial banks can, and do, fail — the Bank’s prudential regulation and supervision helps to ensure that these failures happen rarely and in an orderly way, and deposit insurance protects households in the event of a failure. Consequently, users of existing payment systems can have confidence that the money they send will reliably retain its value, both while it is being used to make a payment, and while it is being held over time.

This safety and confidence may not exist to the same degree for new payment systems that have been proposed by a number of firms, including new entrants and existing technology companies. These proposed payment systems include cryptoassets known as ‘stablecoins’ intended for use in transactions currently processed by retail or wholesale payment systems. Stablecoins propose to *create* the digital tokens or ‘coins’ that they transfer. Stablecoins vary widely in their design features, but most seek to provide stability of value via some form of backing. Depending on the nature of assets backing the ‘coin’, and how they are held, the stablecoin may be unable to provide stability of value and redeemability at par back into commercial or central bank money. Uncertainty about, or large fluctuations in, the value of stablecoins could give rise to similar risks to financial stability associated with the operational or financial failure of the payment system itself. These could include risks to the users’ ability to manage their liquidity or to meet payment obligations, or the risk of such fluctuations causing a collapse in confidence with potential contagion risks for the system. Stablecoins may also not be interoperable with each other and with other payment systems, creating closed loops and inefficiencies.

Consequently, this creation of private money (or money-like instruments) for transactional purposes poses potential risks that go beyond those usually associated with existing payment systems. This is why the FPC recently outlined its expectations for stablecoins used for payments.⁽⁸⁾

Stablecoins will only be widely adopted if they provide functionality and efficiency benefits over existing payment systems. But given the risks they could pose, it may be worth asking if CBDC can be designed to better meet those needs. CBDC may be able to provide better payment services, backed by risk-free central bank money, and reduce the demand for new privately issued money-like instruments.

Supporting competition, efficiency and innovation in payments

While the safety and resilience of payment systems is essential, a safe payment system is only beneficial if people use it. Users therefore need fast, efficient, user-friendly and inclusive services, and innovation, driven by competition, is important in the payments landscape.

There are opportunities for improvements to address potential market failures in existing payment services. For example, while card payments appear near instantaneous to the user, the merchant can wait up to three days to receive funds. There are significant efforts underway to further improve existing payment systems (detailed in the appendix) but to the extent these initiatives do not fully resolve such issues, a CBDC could possibly help to enhance the speed and efficiency of UK payments. This could be both directly — through offering a fast and efficient payment service to users — but also indirectly through creating a more competitive payments landscape.

A well-designed, robust, open, CBDC platform could enable a wide range of firms to compete to offer CBDC-related payment services, and importantly to innovate in the payment services they provide to consumers,

(8) The FPC recently announced that the current regulatory framework may need adjustment in order to accommodate innovation in the payments sector (of which CBDC is one potential example). (*Financial Stability Report*, Bank of England (2019c)). The Bank is also a member of the Cryptoassets Taskforce, which was announced in March 2018 by the Chancellor of the Exchequer as part of the government’s FinTech Sector Strategy. The Taskforce consists of HM Treasury, the Financial Conduct Authority and the Bank of England, and is working to develop a response to cryptoassets, stablecoins and distributed ledger technology.

and the ways in which these are integrated into the digital economy. In doing so, the introduction of CBDC could support competition on both cost and quality of payments services.

Increased competition and innovation could have benefits for the wider economy. Changes in payments behaviour shows that consumers will adopt the methods that are most convenient, such as cards, even though these methods might have a higher cost for businesses. Since payment costs will ultimately be passed on to consumers, there would be net benefits for consumers and businesses if CBDC were able to provide greater convenience at lower cost.

Meeting future payments needs in a digital economy

The next generation of payments will need to support a more digital economy and allow for seamless connections between different services used by households and businesses. As a new system, CBDC could be designed with this in mind, supporting the wider economy.

For example, CBDC could facilitate 'programmable money' (discussed in Chapter 6.4), by enabling transactions to occur according to certain conditions, rules or events.⁽⁹⁾ There will be many potential applications of this functionality, including integration with physical devices or Internet-of-Things (IoT) applications. Examples might include the automatic routing of tax payments to tax authorities at point of sale, shares automatically paying dividends directly to shareholders, or electricity meters paying suppliers directly based on power usage. CBDC might also enable the use of micropayments (payments for very small amounts — discussed in Chapter 4.3) if it allows small transactions to happen at lower cost than happens today. This may increase the volume and frequency of these payments leading to the development of new services that can leverage this capability. This could enable new business models, for things like paying for digital media (eg paying a few pence each time to read individual news articles, rather than needing to sign up to a monthly subscription).

Improving the availability and usability of central bank money

As discussed in Chapter 1.1, currently households and (non-financial) businesses are only able to use central bank money in the form of banknotes. CBDC would also enable them to hold central bank money in electronic form, and use it to make payments. This would increase the availability and utility of central bank money, allowing it to be used in a much wider range of situations than physical cash. Central bank money (whether cash, central bank reserves or potentially CBDC) plays a fundamental role in supporting monetary and financial stability by acting as a risk-free form of money that provides the ultimate means of settlement for all sterling payments in the economy. This means that the introduction of CBDC could enhance the way the Bank maintains monetary and financial stability, through providing a new form of central bank money and a new payments infrastructure. This could have a range of benefits, including strengthening the pass-through of monetary policy changes to the wider economy (discussed in Chapter 5), and increasing the resilience of the payment system.

This increased availability of central bank money also poses risks. The initial introduction of CBDC is likely to lead to some substitution away from the forms of money currently used by households and businesses (ie cash and bank deposits). If this substitution was very large, it could reduce commercial bank funding, with potentially harmful impacts on the level of credit that banks could provide. Consequently, CBDC needs to be carefully designed to manage the impact on monetary policy and financial stability. These considerations are discussed in depth in Chapter 5.

Addressing the consequences of a decline in cash

Physical cash has certain unique characteristics that would be lost if it were to fall out of general use. For example, cash offers a level of privacy in transactions that is not always available with existing electronic payment systems. Cash also has an important role in financial inclusion. In a world where cash becomes less widely used, there is no guarantee that the current private sector provision of the retail payment systems may meet the needs of all users, leaving underbanked groups of society particularly at risk (Sveriges Riksbank (2018)).

(9) See Ali and Narula (2019) who describe how this could be used to enable 'atomic cross chain transactions' to reduce counterparty risk and potentially lower transaction costs and improve financial stability.

Although privacy and financial inclusion do not fall directly within the Bank's remit, they are important issues for society as a whole, which the Bank must take into account. For example, CBDC could be designed in a way that protects users' privacy to a greater extent than some existing payment systems, subject to being fully compliant with all relevant regulations, particularly anti-money laundering requirements (see Chapter 4.6). A well-designed CBDC may also help to boost financial inclusion in an increasingly digital world by being accessible to a broader range of people, potentially in different formats, than private sector solutions.⁽¹⁰⁾

Because of these different characteristics, CBDC would not be a perfect substitute for physical cash. As long as demand for cash remains, the Bank is committed to meeting this demand. For those in society who value the physical nature of cash, the introduction of CBDC is unlikely to affect their payment behaviour, and so we consider that CBDC would likely act as a complement to cash rather than a substitute.

As an enabler for better cross-border payments

For many users, cross-border payments are expensive, slow, and opaque (senders may be unable to know when the payment will be settled, and recipients will not know the charges that will be deducted on an incoming credit) (CPMI (2018)).

One recent proposal to address these issues is the creation of stablecoins. If well designed, stablecoins may be able to meet a clear need for better cross-border payments. But they also introduce risks, as highlighted by the FPC (Bank of England (2019b)) and the G7 Working Group on Stablecoins (2019). Consequently, CBDC may offer a safer way to provide better cross-border payments. For example, central banks may be able to work together to link domestic CBDCs in a way that enables fast and efficient cross-border payments. Individual domestic CBDCs could be designed around a common set of standards intended to support interoperability. This might enable 'atomic' transactions between CBDC systems: where the transfer of CBDC in one currency is linked with a transfer of CBDC in another currency, in a way that ensures each transfer occurs if — and only if — the other does.

The Bank is also actively working with other central banks and finance ministries to consider public and private actions to improve the existing cross-border payment system. For example, the Bank is involved in the CPMI's Cross-border Payments Task Force, and will feed into G20 work on enhancing cross-border payments.

(10) Financial inclusion is a prominent argument for CBDC in developing countries where the banking and payments system are underdeveloped. In these countries, the provision of basic accounts and an electronic payment system by the central bank could make a significant difference to financial inclusion. The UK has a relatively high level of financial inclusion, with 98% of adults in possession of a bank account in 2018. (Calculated from figures in McKay, Rowlingson and Overton (2019)).

3 Objectives and design principles

Key points

- Any CBDC payment system would need to be designed with a clear use case in mind. For this paper, we focus on domestic retail payments — payments that involve households and/or small or medium-sized businesses, in sterling, within the UK. Work is taking place elsewhere to address wholesale and cross-border payments.
- Our overall objective for CBDC payments is that households and businesses should be able to make fast, efficient and reliable payments, and benefit from a resilient, inclusive, innovative, and competitive payment system. This overall objective sets our design principles, which in turn determine our choices around economic design, functionality, provision and technology.
- An approach to CBDC where the Bank of England does everything, with no private sector involvement, is unlikely to meet most of our design principles. Such a CBDC may be resilient, fast and reliable. But it would not be open to competition, may not support innovation, and would not be designed around the respective strengths of the Bank and private sector. For this reason, and in order to more likely meet these principles, we consider a model which has both central bank and private sector involvement, as presented in Chapter 4.

3.1 Objective for CBDC payments

The Bank's monetary and financial stability objectives require that any CBDC payment system would be reliable, resilient and secure. But a safe payment system is only useful if people use it, which means CBDC would also need to enable fast, efficient, user-friendly and inclusive services. This in turn requires that a CBDC payment system would be open to innovation and competition, and built around the comparative advantage (relative strengths) of the Bank and the private sector. Consequently, for the purpose of this paper we have taken the following broad objective for CBDC payments:

Households and businesses should be able to make fast, efficient and reliable payments, and benefit from an inclusive, innovative, competitive and resilient payment system.

Types of payments in scope

Different users need to make different types of payments, so it would be challenging, if not impossible, to build a single payment method that meets the needs of all users in an optimal way. For example, households making small value payments in shops have different needs to a large corporate paying a company in a different country for an order worth millions of pounds. This is why we have chosen to focus this paper on *retail* CBDC, covering payments which are: domestic (within the UK), retail (made by households and businesses — CBDC 'users') and in one currency (sterling). **Table 3.A** shows the types of payments that would fall within this scope. Our focus on domestic retail payments means that domestic wholesale and all cross-border payments are outside the scope of this paper. However, the Bank is engaged in a range of other initiatives to enhance the functioning of these payment types — see Box 2 overleaf.

Table 3.A Example types of payments in scope

From	To	For	Current payment methods available
Households	Businesses	Goods and services, in shop or online	Cash or debit/credit cards
Households	Businesses	Recurring bills	Direct debit/standing order
Households	Households	Gifts, rent etc.	Cash or faster payments
Businesses	Households	Wages to employees	Faster payments or Bacs
Businesses (small to medium)	Businesses (small to medium)	Goods and services from suppliers	Faster payments or debit/credit cards

Box 2

Types of payments out of scope

Domestic wholesale payments

In the UK these payments are usually handled by CHAPS, the high-value payment system provided by the Bank of England. Users of wholesale payments have very specific requirements, such as the need for banks making those payments to manage their liquidity (ie holdings of central bank money) as efficiently as possible. Improvements in existing high-value payments are being addressed by the Bank's RTGS Renewal Programme, which will rebuild the Real-Time Gross Settlement System that underpins CHAPS and other UK payment systems. This programme will implement a range of enhancements seeking to strengthen resilience and flexibility to respond to emerging threats. This will facilitate greater direct access to central bank money settlement for financial institutions and infrastructures. Furthermore, it will promote harmonisation and convergence with critical domestic and international payment systems.

The Bank is also separately considering how alternative high-value payment systems, which are sometimes described as 'wholesale CBDC', could be supported, and will consult on this shortly.

Cross-border payments (retail and wholesale)

Although CBDCs may ultimately enable new ways to make cross-border payments, this type of payment is significantly more complex than domestic payments. Cross-border payments and payments involving certain jurisdictions may have a higher risk profile for the purposes of anti-money laundering and sanctions legislation. Additional frictions for cross-border payments include lack of overlap of opening hours of payment systems across the world, liquidity inefficiencies, lack of harmonised messaging and different access requirements to payment systems.

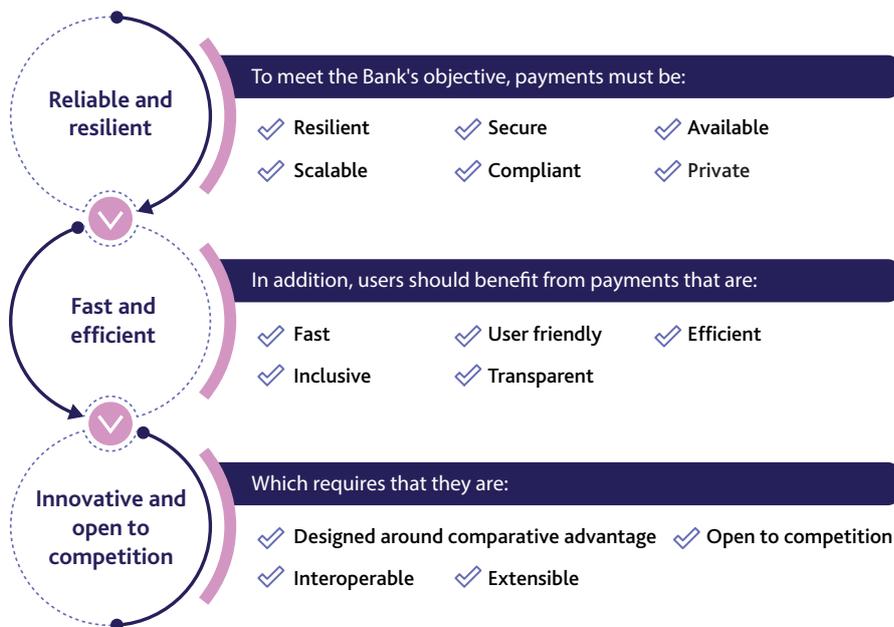
Removing these frictions will require international co-ordination between central banks, commercial banks and other payment providers. Work to improve the existing cross-border payment system is a part of the Bank's Future of Finance initiative,⁽¹⁾ and a key deliverable of the G20 agenda. In co-ordination with the Committee on Payment and Market Infrastructures (CPMI), the Financial Stability Board (FSB) will develop and deliver to the G20 a roadmap for how to enhance global cross-border payments. The Bank is closely involved in both the FSB's work and the CPMI's Cross-Border Payments Task Force.

(1) The Bank has also worked with Bank of Canada and the Monetary Authority of Singapore to explore ways to improve cross-border payments (Bank of Canada *et al* (2019)).

3.2 Design principles

Our overall objective can be split into the following design principles. For each, we have described an ideal case. However, in the real world there will be trade-offs between different principles, making it impossible to achieve the best outcome for every principle. Consequently, if we were to issue CBDC, we would need to make careful choices about which principles to prioritise, and the optimal trade-offs between them.

Figure 3.1 Design principles for retail payments



Reliable and resilient

The Bank's primary objectives require that any CBDC payment system must be reliable and resilient. This requires that any CBDC should need to be:

- **Resilient:** any CBDC payment system must be able to recover from operational disruption, for example from hardware or software failures. It is also important to minimise any credit and liquidity risk arising in the wider CBDC ecosystem.
- **Secure:** CBDC should follow the highest standards of cyber-security against fraud and cyber-attacks. There would need to be clear policies around who is responsible for redress in the case of fraudulent payments.
- **Available:** CBDC should provide 24/7 payments with no planned downtime.
- **Scalable:** the technology powering CBDC payments should be able to handle increased volumes if demand for CBDC payments increases significantly.
- **Compliant:** CBDC should be compliant with regulations around anti-money laundering (AML), the countering the financing of terrorism (CFT), and sanctions.
- **Private:** CBDC should be compatible with the General Data Protection Regulation (GDPR).

Fast and efficient

This consideration is about ensuring that users benefit from using CBDC. This means that CBDC payments would need to be:

- **Fast:** the process from the payer (sender) initiating a payment to the payee (recipient) receiving the funds, should complete as quickly as possible, with certainty over completion.
- **User friendly:** users should be able to make a payment intuitively, in the minimum number of steps, with a minimum required level of technical literacy.
- **Efficient:** the payment should happen in the simplest way, to ensure that the cost of CBDC payments would be as low as possible (subject to the need to ensure the system is resilient and secure).
- **Transparent:** the costs of making payments in CBDC should be clear to all users.
- **Inclusive:** CBDC payment systems should be designed to minimise barriers to use from (a) technical literacy, (b) disabilities, and (c) access to hardware (eg avoiding reliance on latest smartphones) or (d) access to mobile data networks (eg in rural areas).

Innovation and open to competition

This consideration is about ensuring that the CBDC system as a whole remains open to innovation and competition, and evolves with changing user needs. This means that any CBDC would need to be:

- **Designed around comparative advantage:** the structure of a CBDC should build on the Bank and private sector's respective strengths and expertise, so long as it does not compromise resilience, security or confer unfair commercial advantage.
- **Open to competition:** the structure of a CBDC should facilitate a competitive market for providers of CBDC-related payment services. This requires an appropriate regulatory structure that protects consumers while minimising barriers to entry. The design of CBDC should also ensure that there are no structural factors that would lead to a winner take all market dynamic in the provision of CBDC-related services.
- **Interoperable:** CBDC should be designed to avoid creating closed-loop payment systems, in which payments can only be made between users of the same payments provider. Instead, CBDC payments should be interoperable, allowing payments between users of different providers, and between users of CBDC and users of deposit accounts. Furthermore, CBDC should also be designed to interoperate with other countries' CBDC payment systems (to support future cross-border payments in CBDC). CBDC should also avoid tying providers into specific technologies or technology providers.
- **Extensible:** it should be possible for private sector innovators to build additional services on top of the CBDC platform, and support innovative use cases that we cannot currently foresee. The design of CBDC should not limit the range of services that can be provided in the future, and recognise that the functionality and infrastructure will need to evolve over time.

3.3 The benefits of private sector involvement

In one possible CBDC model, the Bank would exclusively provide all CBDC-related services. It would need to provide the entire core technology that records CBDC accounts and transactions. In addition, the Bank would also need to provide all customer-facing services, including the user interface and point-of-sale integrations, so that people could pay with CBDC in shops and online.

However, an approach where the Bank exclusively provides all CBDC-related services is less likely to achieve our overall objectives or meet our design principles than an approach that involves both the Bank and the private sector:

- Exclusive central bank provision would not be open to competition, because there is no role for any participant other than the Bank to provide CBDC-related services.

- This approach may not support innovation, because any new features or functionality would have to be implemented by the Bank. This would also mean that this model would not be extensible.
- This approach does not play to the Bank's comparative advantage, as it involves building services for large numbers of retail customers rather than for financial institutions. Building user-friendly services for the general public is a strength of the UK private sector, which can also build on this experience to ensure they provide inclusive services.
- This approach also raises considerations about privacy, because all data on users' identities and transactions would need to be stored by the Bank.

This approach may be appropriate in countries with low financial inclusion, where the private sector is unable or unwilling to provide CBDC-related payments infrastructure or services. But we do not think this model would be appropriate for a country like the UK, with a high level of financial inclusion and an innovative private payments sector. Therefore, we will not further develop this model of CBDC, where the Bank exclusively provides all CBDC-related services, in this paper.

4 A platform model of CBDC

Key points

- Based on our design principles, we have set out an illustrative CBDC model as a basis for further discussion and research.
- In this model, CBDC would serve as a payments platform on which the private sector could innovate. There are two key elements of the platform: (1) a core ledger, provided by the Bank, would record CBDC and process payments, and (2) private sector 'Payment Interface Providers' would handle the interaction with end-users of CBDC and provide additional payments functionality through overlay services.
- Payment Interface Providers would need to meet criteria set by the Bank and relevant regulators before they start to offer CBDC-related services. Furthermore, they should be supervised on an ongoing basis, in order to ensure consumer protection and the resilience of the CBDC system. The CBDC system as a whole would be designed to be compliant with anti-money laundering and data protection regulations.
- This platform model has the potential to meet many of our design principles, depending on its final design.

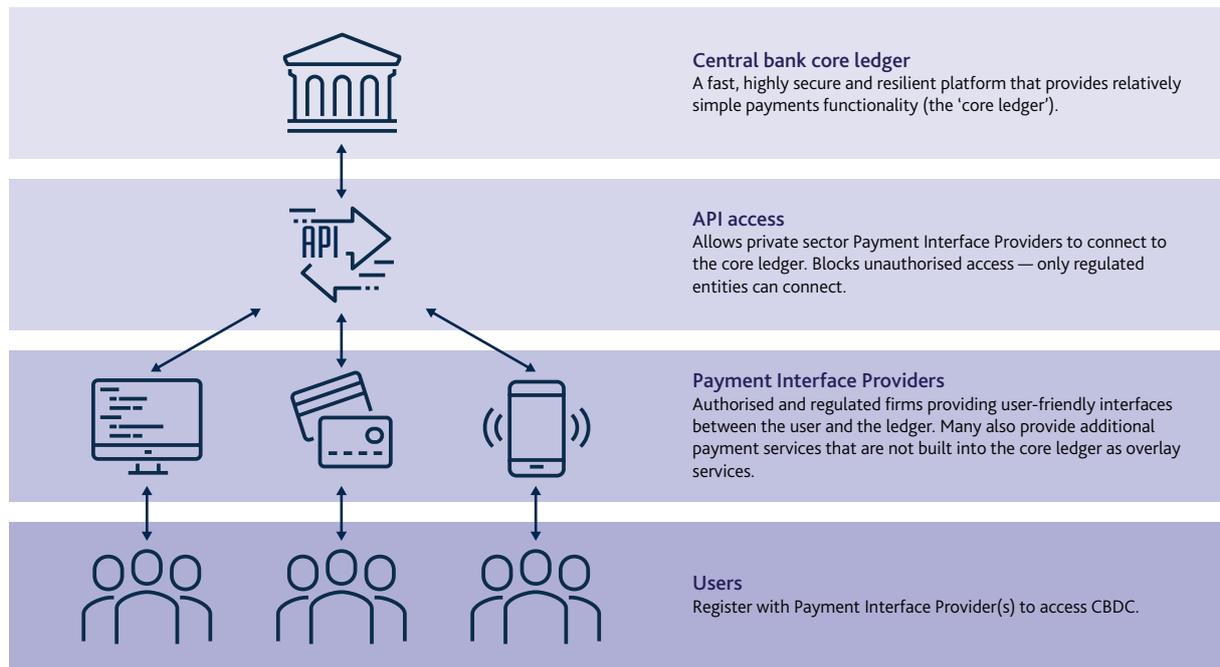
4.1 Overview

There would be two main elements to any CBDC: (1) the CBDC itself (ie access to a new form of central bank money) and (2) the CBDC infrastructure that allows CBDC to be transferred and used for payments. This chapter focuses on infrastructure, and presents a hypothetical model of CBDC as a public-private payment *platform*. This model has been built around the design principles we outlined in Chapter 3, and is intended as a basis for further discussion and research, rather than a proposal for a CBDC. Outlining an illustrative model helps us explore the practicalities, opportunities and implications of introducing CBDC, and allows us to evaluate at a high level how well a particular design of CBDC might meet our objectives. The model will also provoke discussion by stakeholders of the benefits, challenges and design choices involved.

In this *platform* model (Figure 4.1), the Bank would build a *fast, highly secure and resilient* technology platform — the '*core ledger*' — which would provide the minimum necessary functionality for CBDC payments. This would serve as the platform on which private sector firms, called *Payment Interface Providers*,⁽¹⁾ could connect in order to provide customer-facing CBDC payment services. These firms might also build '*overlay services*' — additional functionality that is not part of the Bank's core ledger, but which could be provided as a value-added service for some, or all, of their users. The Bank could impose *standards* for these overlay services, alongside wider regulation, to ensure that they were secure, resilient and interoperable with the wider CBDC payment system. The Bank would otherwise allow the private sector to innovate payment services for specific use cases.

(1) The term *Payment Interface Provider* is not intended to have the same meaning as a 'Payment Initiation Service Provider' under the Payment Services Directive 2015. Further engagement would need to be undertaken on the regulatory classification of firms participating in a CBDC system. Regulatory considerations are covered in Chapter 4.5.

Figure 4.1 Platform model of CBDC



This 'layered architecture' approach to technology infrastructure is becoming a common approach in payments, as it can help facilitate competition, innovation and extensibility. Similar approaches have been taken by the [New Payments Platform](#) in Australia, [Payments Canada's Modernization](#) programme, and it is also the model proposed in Pay.UK's [New Payments Architecture Programme](#) in the UK (see appendix).

There are complex considerations in each area of CBDC design, and many open questions that require further research. The platform model is not the only way that CBDC could be structured, so we may choose to explore other models in the future.

4.2 Key components

(a) Central bank core ledger

The centre of the CBDC payment system would be a *core ledger* (database) that records CBDC value itself, and processes the payments (transactions) made using CBDC. In this illustrative model, the functionality of the core ledger could be limited to the essential features required to enable CBDC payments. For example, it could provide push payments ie payments initiated by the payer (sender) and the ability to query latest balances or transaction history. Limiting the range of functionality to the essential features could make it easier to build a system that is simple, fast and resilient, and could allow most of the innovation in CBDC payment functionality to happen in the private sector through overlay services (discussed below).

In this model, the core ledger would be accompanied by an *API* (Application Programming Interface) to allow third-party Payment Interface Providers to securely send payment instructions and ask for updates from the ledger. To ensure resilience, security and integrity, only entities approved by the Bank, such as Payment Interface Providers,⁽²⁾ would be able to connect to the core ledger (See also Chapter 6).

Although the Bank could operate the core ledger itself, there is also the possibility of distributing or decentralising aspects of the maintenance of the ledger and processing of transactions. Chapter 6 considers the technology benefits, costs and trade-offs involved in adding degrees of distribution and decentralisation to a CBDC payment system. Whatever technology approach is used, it is essential that only the Bank can 'create' or 'destroy' CBDC.

(2) Regulatory considerations are explored in Chapter 4.5.

(b) Payment Interface Providers

In the platform model, *Payment Interface Providers* would be private sector firms that would manage all the interaction with users of CBDC and provide overlay services that extend the functionality of CBDC. In practical terms, they could:

- Provide a user-friendly interface, such as a mobile application or website, to allow the user to initiate payments and manage their CBDC.
- Apply Know Your Customer checks to verify the identity of users (or commission a third-party service to do this).
- Register one or more accounts for the user in the core ledger. This account could be pseudonymous on the core ledger, meaning that the core ledger would not need to record identity information. However, the Payment Interface Provider would record the identity of the user on its own systems, and would know which pseudonymous account(s) the user holds at the Bank.
- Authenticate the user when they initiate payments, to protect them against fraud (eg if the user's phone has been stolen), protect their personal data and ensure cyber-resilience.
- Apply anti-money laundering and sanctions checks to relevant payments (or commission a third-party service to do this).
- Develop overlay services (see below) to provide additional functionality.
- Some Payment Interface Providers might also want to provide 'merchant services' to enable retailers and businesses to take CBDC payments from consumers.

In the basic model above, Payment Interface Providers would maintain an individual account in the core ledger for every user. Payments between users would be processed through the core ledger even if both users have the same Payment Interface Provider. An alternative model could be for each Payment Interface Provider to maintain a single 'pooled' account in the ledger, which holds all of their users' CBDC. The Payment Interface Provider would record how the funds in the pooled account are divided between its users. Payments between two users of the same Payment Interface Provider could then be processed within the Payment Interface Provider's own systems, rather than through the core ledger. However, payments between a user of the Payment Interface Provider and any other Payment Interface Provider would still need to go through the core ledger.

Although some Payment Interface Providers would be payments-focused firms, other types of firms may also want to provide CBDC-related services, if this enhances the service they provide, makes their services more 'sticky', or serves as a loss-leader to attract customers for other services. For example, websites that provide marketplaces for retailers may be able to integrate CBDC payments for those retailers. Some online accounting platforms for businesses may want to become Payment Interface Providers, as they could monitor incoming payments, reconcile them into the firm's financial accounts, and also initiate outgoing payments for invoices and salary payments.

(c) Overlay services

By design, the core ledger would have relatively simple functionality in this model, but Payment Interface Providers could develop 'overlay' services to provide additional functionality. This means that Payment Interface Providers could build new services, for example, those that are only needed by a subset of users, or which meet new use cases that emerge in the future (as discussed below). The standards and expectations set by the Bank and relevant regulators could be important here to ensure that overlay services are secure, resilient, open to competition, interoperable, and meet society's expectations of confidence and trust in money.

New use cases will emerge that we cannot foresee. Therefore, it is important to ensure the core ledger provided the minimum functionality or building blocks to enable Payment Interface Providers to develop new services. Furthermore, it is important that the system as a whole was extensible and open to innovation.

4.3 CBDC payments functionality

In this model, all CBDC payments would be settled immediately ('real time') in central bank money. Payments would be settled 'gross'.⁽³⁾ This means that CBDC would provide finality of settlement: when the payment is made, it is settled immediately. The money would then belong to the recipient and the payment would be irrevocable (although returns and refunds could of course be made by initiating a payment in the opposite direction).

Basic payments

The core ledger could provide the basic functionality for one-off 'push' payments, where the payment is initiated by the payer, via their Payment Interface Provider. Payment Interface Providers could then develop the full range of payment types as overlay services. For example, these could include push payments (initiated by the payer), pull payments (initiated by the payee) and recurring payments.

Point-of-sale payments for businesses

Some Payment Interface Providers might want to provide merchant services that allow businesses to accept CBDC payments, either in person at the point-of-sale (PoS) or remotely (ie on a website). For shops and in-person sales, many traditional cash registers have been replaced by newer PoS devices that feature the ability to integrate new payment services. CBDC would need to be designed to be compatible with these PoS systems. For smaller businesses with older or more basic tills, even a low-end smartphone should serve as a terminal to accept CBDC payments.

Offline payments

Most CBDC payments would need to connect to the core ledger, which means that there would need to be a working data connection between the payer, payee and core ledger. This may not always be possible. For example, mobile data connections may be weak or non-existent in some instances. This would limit the usability and usefulness of CBDC, and so there may need to be a simple way for payments to be made, without immediate 'online' reference to the core ledger. The challenge is finding a way to enable offline payments without exposing either the buyer, seller, or Bank of England to the risk that the payment may not ultimately be settled. Another challenge is to build offline payments functionality in a way that it cannot be abused by fraudsters.

Existing card payments already allow some 'offline' payments, where the card terminal does not (or cannot) connect for an authorisation, for example when using contactless cards to pay for a journey on the transport network.⁽⁴⁾ But these payments require the merchant to bear the risk that the payer does not actually have the necessary funds to fulfil the transaction, and so these payments are generally only allowed below a certain value limit. Work is underway in some central banks and in the private sector to find solutions that allow this kind of offline device-to-device payments in CBDC in a way that does not create any credit risk, but this technology is still very experimental.

Bulk payments

Large companies often need to send (or request) multiple payments at the same time, for example making payroll payments to hundreds or thousands of employees, or requesting bill payments from thousands or even millions of customers. These bulk payments are not usually time critical, although they may need to be made within a certain window (eg midnight and 6am on pay day). It may be beneficial to incentivise Payment Interface Providers to

(3) Most retail payment systems use a settlement model known as 'deferred net settlement' (DNS), where the underlying settlement obligations between customers of different payment providers are netted against each other. This creates net obligations between banks, which are settled by larger payments in central bank money. This model significantly reduces the amount of funds that must be transferred between the payment providers. However, it only reduces liquidity needs when there are a large number of offsetting payments between a small number of participants. In a CBDC context, there are a large number of participants, with each participant making relatively few payments, and few of those payments can be offset against payments coming in the opposite direction. Consequently, this model is not applicable to CBDC.

(4) [Processing Card Transactions](#), The UK Cards Association.

queue these types of bulk payments and send them when they know the core ledger will be significantly below peak demand for 'immediate' payments.

Micropayments

CBDC could enable micropayments — payments for very small amounts — supporting the development of Internet-of-Things (IoT) applications, which connect networks of physical devices, like smartphones, vehicles, homes, and home appliances. Micropayments could also support alternative revenue models for digital media (for example shifting away from current subscription and ad-supported models). This is particularly the case as, for many existing payment systems, the cost to process a micropayment may be greater than the value of the payment itself.

Programmability

As discussed in Chapter 2.4, CBDC might facilitate 'programmable money', where payments occur according to specified conditions, rules or events. This programmability could be implemented via the use of 'smart contracts', which are discussed in Chapter 6.4. This functionality could also enable 'atomic' transactions, where the transfer of CBDC with another asset is linked in such a way as to ensure that the transfer of CBDC occurs if and only if the transfer of the other asset also occurs. If multiple different national CBDCs existed, the other asset might be a CBDC transaction in another currency, enabling Payment-versus-Payment (PvP) for cross-currency transactions. Or the other asset could be a physical or financial asset (eg a parcel, or a security), enabling Delivery-versus-Payment (DvP).

4.4 Incentives for private sector involvement

In Chapter 3.3 we concluded that a model which relied exclusively on the Bank to provide all CBDC-related services would be unlikely to meet most of our design principles. This means that there would need to be a significant role for the private sector, and incentives for private sector operators to undertake the services described above. These firms would need to ensure that they had viable opportunities to develop value-add services and generate revenues from functions beyond those offered by the core ledger.

The Bank would also incur costs in building and running the core ledger, and these would need to be recovered, possibly by small transaction fees charged to Payment Interface Providers. The Payment Interface Providers themselves would incur costs in getting established and building and maintaining their own systems, applications and so on.

It is not for central banks to decide the revenue model for private sector firms, but some possibilities are demonstrated by existing payment service providers. Firms could generate revenue directly from providing CBDC payment services, for example by charging transaction fees or monthly account fees. Some firms might seek to provide CBDC-related services at cost or even as loss leader if it reduces third party payment costs in their core business, attracts new customers, enhances the usefulness of other products they offer or has synergies with their wider business model. In all cases, the way that Payment Interface Providers charge — or otherwise generate revenue on the services they provide — should be transparent to users.

4.5 Regulatory framework

To ensure financial stability, the Bank of England regulates and supervises systemically important payment systems (the core infrastructure that undertakes the activities of authorisation, clearing and settlement) and designated critical providers to them. In addition, to ensure consumer protection and resilience, payment service providers are subject to regulation by the Financial Conduct Authority (FCA). The Payment Systems Regulator (PSR) is the economic regulator for the payment systems and their participants in the UK. The Bank of England's Financial Policy Committee (FPC) has recently [announced](#) that the current regulatory framework may need adjustment in order to accommodate innovation in the payments sector (of which CBDC is one potential example). The FPC [outlined](#) three principles that payments regulation should aim to achieve, which UK authorities are currently considering, including as part of HM Treasury's review of the payments landscape:

- i. Reflect the financial stability risk, rather than the legal form, of payment activities;
- ii. Ensure end-to-end operational and financial resilience across payment chains that are critical for the smooth functioning of the economy; and
- iii. Ensure that sufficient information is available to monitor payment activities so that emerging risks to financial stability can be identified and addressed appropriately.

Payment Interface Providers would need to meet these and any other criteria set by the Bank and relevant regulators before they start to offer CBDC-related services. This would include a requirement that entities have the appropriate regulatory authorisation(s), and would be supervised on an ongoing basis. There would need to be consideration of how any CBDC-related regulation might sit alongside, or within existing regulation and oversight, which participants may be subject to. There would need to be an agreed approach across relevant regulators regarding the criteria for authorisation and the precise requirements placed on Payment Interface Providers undertaking payment activities using the CBDC infrastructure.

Under any revised regulatory framework, Payment Interface Providers (and any other firms in the CBDC ecosystem) would need to be subject to appropriate regulation, according to the risks they pose, and would need to achieve equivalent standards to current payment firms. This would include ensuring that all firms in the CBDC ecosystem are subject to the relevant standards of operational and financial resilience in order to mitigate risks that their operational or financial failure could pose to the end-to-end payments chain. As noted by the FPC, 'firms that are systemically important should be subject to standards of operational and financial resilience that reflect the risks they pose', and this would apply to firms involved in CBDC provision. They would also need to conform to the conduct and other standards set by the FCA and other relevant regulators.

Setting standards and requirements

The Bank (and relevant regulators) would also need to set standards to ensure that the CBDC payments system was resilient and reliable, open and interoperable. However, the standards should not dictate how CBDC-related services should be built, or what technology Payment Interface Providers or overlay services would need to use. These standards and requirements collectively make up the payment scheme that would apply to CBDC, and could define:

- Standards for interoperability between different Payment Interface Providers, including how payments can be made between different customers of different Payment Interface Providers, and how a customer can transfer their service to another Payment Interface Provider.
- Standards or expectations for Payment Interface Providers and overlay payment services they provide, potentially including minimum standards for security and identity. This would ensure resilience, interoperability and appropriate levels of consumer protection.
- Guidelines and principles for CBDC Payment Initiators' user interfaces (eg applications).
- Messaging standards used in CBDC payments (such as adopting the ISO 20022 data standard) and mandating the use of identifiers like the Legal Entity Identifier (LEI). These measures could support interoperability, extensibility and security of CBDC.
- Rules about who bears responsibility when CBDC payments go wrong, including in cases of fraud, failed transactions, cyber-risks and privacy.

Box 3

Other approaches to providing CBDC

An alternative to CBDC would be for private sector firms to issue liabilities which were fully backed by funds held at the central bank. These firms would act as intermediaries between the central bank and the end-users. Providing that the regulatory framework ensures that these firms' liabilities were always fully backed by funds at the central bank, these liabilities could share many of the characteristics of a CBDC that is directly issued by the central bank. However these liabilities would not be central bank money, as holders would not hold a direct claim on the central bank.

Such an approach has been suggested by some stablecoin proposals. It has also been described by some researchers as 'synthetic CBDC' (Adrian and Mancini-Griffoli (2019)).

In line with the Financial Policy Committee's principles for regulation of payments and expectations relating to stablecoins, such an approach would require appropriate regulation and supervision to ensure that equivalent standards apply as with existing forms of private money.

4.6 Compliance with anti-money laundering (AML), combating the financing of terrorism (CFT) and sanctions

A CBDC payment system would need to be compliant with AML and CFT regulations and requirements. This means the identity of CBDC users would need to be known to at least some authority or institution in the wider CBDC network who can validate the legitimacy of their transaction. In the platform model, one possibility is that the core ledger only stores pseudonymous accounts and balances, but that each account in the core ledger is linked to a Payment Interface Provider who knows the identity of each user. Payment Interface Providers would be responsible for applying AML checks to users, and for reporting suspicious transactions to the authorities.

This arrangement means that the Bank would not hold granular personal data on any user, reducing the privacy concerns that could arise in connection with holding personal user data, but AML requirements could still be met by the CBDC system as a whole.

AML responsibilities could be handled entirely by the Payment Interface Providers. However, it is also possible that new business models could emerge with dedicated firms that verify users' identity and use new techniques to identify suspicious activity. The field of digital identity is currently experiencing significant developments. Therefore, the current model, where payment providers apply AML using their own systems, does not have to be the only model in use if CBDC is eventually introduced.

4.7 Privacy and data protection

It will be essential to consider how privacy is respected and how data is protected in a CBDC system. Privacy and data protection is an issue that is of concern to policymakers in government and other authorities⁽⁵⁾ and should be considered carefully when designing CBDC.

Any CBDC system would need to be compatible with privacy regulations, such as the 2018 General Data Protection Regulation (GDPR), which would apply to the Bank of England, Payment Interface Providers and any other firms providing CBDC-related services. In simple terms, this means that users should have control over how their data is used and who it is shared with. Any third-party processing data will need to observe applicable data protection legislation.

(5) In the UK, this would include the Department for Digital, Culture, Media and Sport (DCMS) and the Information Commissioners' Office (ICO).

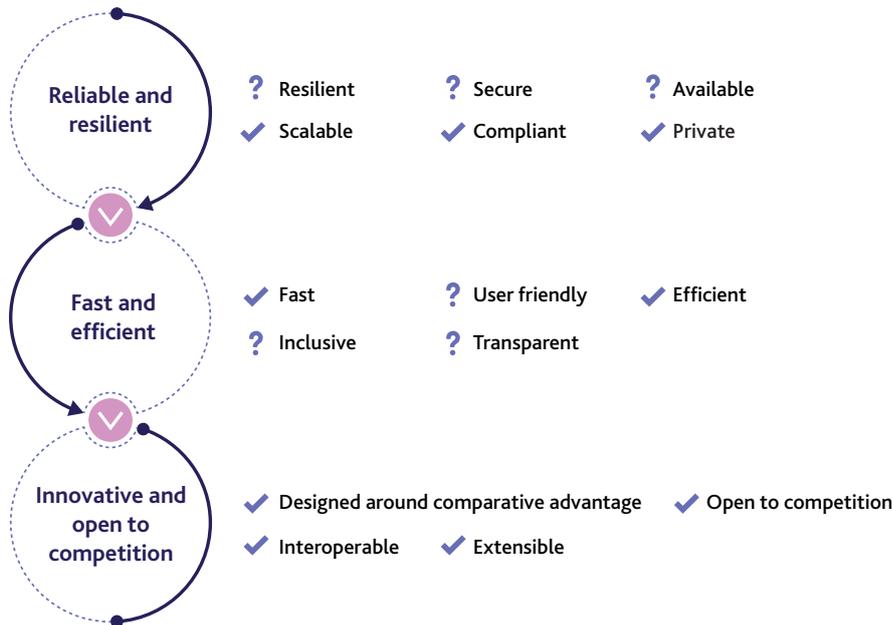
The appropriate degree of anonymity in a CBDC system is a political and social question, rather than a narrow technical question. As discussed above, CBDC would need to be compliant with AML regulations, which rules out truly anonymous payments. However, CBDC could be designed to protect privacy and give users control over who they share data with, even if CBDC payments are not truly anonymous (or secret). For example, a user may legitimately want to make a payment to a supermarket without sharing their identity with the supermarket, as this would allow the supermarket to build a picture of their shopping habits. In most cases, the payer should be able to pay without revealing their identity to the payee. In this sense, they could have anonymity with regards to other users, without having anonymity with regards to law enforcement.

Some discussions of CBDC assume that CBDC is equivalent to cash and so should offer the same degree of anonymity in payments. When a payer hands over cash to a payee, for example in a shop, the payee does not receive any data about the identity of the payer, and there is no digital record that links the payer and payee.⁽⁶⁾ But the fact that an in-person cash payment provides an anonymous means of payment is a result of the nature of this payment method. The Bank does not have a specific mandate to provide untraceable or anonymous payment methods.

4.8 How the platform model measures against our design principles

The platform model of CBDC has the potential to meet many of the objectives and design principles that we outlined in Chapter 3.2. However, as shown in **Figure 4.2**, the ultimate outcome is not certain and will depend on the final design of CBDC, and the choices made about trade-offs between different design principles.

Figure 4.2 How the platform model may meet our design principles



Resilient and reliable

- **Scalable:** because the core ledger would have relatively simple functionality, it should be possible to scale its capacity as demand varies.
- **Compliant:** the CBDC system would be designed to be compliant with AML requirements.
- **Private:** The CBDC system would be designed to be compliant with GDPR.

(6) In some circumstances, there may be identification requirements even where cash is used, such as for high-value purchases.

Fast and efficient

- **Fast:** the system could provide instant real-time payments in central bank money, so payers (including merchants) can receive funds instantly.
- **Efficient:** the core ledger could be built with relatively simple functionality, so that it would be as efficient and cost-effective as possible. Additional functionality that would only be used by a subset of users could be provided by Payment Interface Providers through overlay services. This would ensure that the cost of providing for more complex user needs falls on the users of those services, rather than being distributed across all users.

Innovative and open to competition

- **Designed around comparative advantage:** the platform model allows the Bank and the private sector to focus on their respective strengths. The Bank could focus on building a highly resilient infrastructure (the core ledger), while the private sector Payment Interface Providers could focus on the user experience, by providing customer services, and building user-friendly services.
- **Open to competition:** firms could compete to provide CBDC-related services. An appropriate regulatory structure could protect consumers while minimising barriers to entry.
- **Interoperable:** the Bank could set requirements to ensure that any CBDC account should be able to pay any other CBDC account, regardless of the Payment Interface Provider associated with each account. This will ensure that the CBDC payments network does not fragment into closed loops (which would reduce the usefulness of CBDC overall, and could lead to the emergence of one or two dominant Payment Interface Providers).
- **Extensible:** Payment Interface Providers can develop innovative overlay services to provide functionality that is not built into the core ledger, to enable CBDC to meet payment needs as they evolve.

Design principles that may not be met by the platform model

However, some of our design principles are not automatically met by the platform model of CBDC. Additional standards or policy interventions would be needed to ensure that the following design principles are met:

- **Resilient and available:** although the core ledger could be highly resilient and available 24/7, Payment Interface Providers' own systems may be vulnerable to disruption, which would possibly prevent users making payments. Therefore, the Bank would need to set minimum standards for operational resilience.
- **Secure:** the Bank should also set minimum standards for cyber-security and user authentication.
- **Transparent:** policies for other authorities would be needed to ensure that the cost of CBDC was transparent.
- **User-friendly:** private sector Payment Interface Providers could design the user interface for CBDC payment systems, with the most user-friendly services likely to have a competitive advantage.
- **Inclusive:** the Bank and relevant regulators would need to set standards to ensure that Payment Interface Providers build systems that support inclusion and avoid barriers that arise as a result of technical literacy, disabilities or reliance on more expensive hardware (such as smartphones).

5 Economic design and impacts on monetary and financial stability

Key points

- CBDC would be a new form of money, which would for the first time allow households and businesses to directly make electronic payments using central bank money. This change could impact the structure of the banking system and the way that the Bank achieves its primary objectives to maintain monetary and financial stability.
- There are potential benefits and risks of CBDC for monetary policy. For instance, it may support more effective transmission of monetary policy through some channels. But these benefits would have to be weighed against risks, such as the potential effects of disintermediation of the banking sector on credit provision.
- CBDC would only have benefits if households and businesses hold it and use it to make payments. This means they must switch some of their funds out of banknotes and commercial bank deposits and into central bank money in the form of CBDC, so some disintermediation would be inevitable. But a very large or rapid shift from deposits to CBDC could have significant implications for the amount and cost of credit that the banking sector could provide to the economy and the way the Bank achieves its objectives.
- There would be new tools available to the Bank to influence the attractiveness and use of CBDC, and therefore manage the trade-off between benefits and risks. The Bank's existing macro and microprudential tools, alongside the role of deposit insurance, could also help to manage risks.

5.1 Overview

CBDC would be a new form of money, which would for the first time allow households and businesses to directly make *electronic* payments using *central bank* money. While this may seem like a small change, it could have material benefits for households and businesses and could impact the structure of the banking system and the way that the Bank achieves its objectives to maintain monetary and financial stability. For instance, CBDC could, for some transmission channels, increase the speed and extent to which changes in the Bank's policy rate are passed on to households and businesses, and it could alter the amount and cost of credit provided to the economy by the banking sector. For these reasons, CBDC would need to be carefully designed to ensure that the potential benefits for monetary and financial stability, as well as the wider benefits of introducing CBDC for the public, could be realised without jeopardising the Bank's objectives and the financial sector's ability to provide credit and other services to the wider economy.

This chapter discusses how introducing CBDC could affect the balance sheets of the Bank of England and the commercial banking system.⁽¹⁾ It then shows how the introduction of CBDC could affect monetary policy, financial stability and the role of the Bank of England. Finally, it explains how the economic design of CBDC could have important effects on the rate of adoption of CBDC and therefore the extent of these wider impacts. In particular, it focuses on the important design issue of remuneration: whether or not CBDC should pay interest.

5.2 Impact of disintermediation (switching from deposits to CBDC)

CBDC would only have benefits if households and businesses hold it and use it to make payments. This means they must switch some of their funds out of banknotes and commercial bank deposits and into central bank money in the form of CBDC. But this switching from deposits to CBDC can have potentially significant implications on the banking system, monetary policy and financial stability. To understand these implications, it is important to understand the impact of a switch from deposits to CBDC on the balance sheets of the Bank of England and commercial banks.

CBDC would represent a new form of central bank money, which would be issued by the Bank of England. Central bank money, whether cash, central bank reserves (explained in Chapter 1.1) or potentially CBDC, plays a fundamental role in supporting monetary and financial stability by providing the ultimate means of settlement for all sterling payments in the economy.

Like other forms of central bank money, CBDC would be recorded as a liability on the Bank of England's balance sheet (just like banknotes and reserves), and 'backed' (matched) by assets held by the Bank. At present, the majority of these assets are bonds issued by the government, but other backing assets include loans to the banking sector through schemes like the Term Funding Scheme, as well as the Bank's routine liquidity facilities.

In contrast, commercial bank deposits are issued by commercial banks and form an important part of the banking sector's funding. A commercial bank's deposits are recorded as liabilities on its balance sheet, and are backed by its assets, which typically consist of central bank reserves, bonds, loans (such as mortgages), and other financial assets.

If CBDC were introduced, some of the households and businesses that currently hold commercial bank deposits might wish to exchange these deposits for CBDC. This process of converting deposits to CBDC is described in detail in Box 4 but the result is that, absent any other action, commercial banks lose both deposits and assets in equal amounts, and so end up with a smaller balance sheet.

This shrinking of the banking sector's balance sheet is known as 'disintermediation'.⁽²⁾ Some degree of disintermediation is an inevitable consequence of a successful CBDC. However, this disintermediation would result in a lower total volume of funding for banks. Banks would need to consider how to react to a prospective loss of deposit funding, and the impact it would have on their ability to provide lending to the wider economy. They could react by paying a higher interest rate on deposits in order to limit any further outflows to CBDC,⁽³⁾ or they could seek to replace lost deposit funding with alternatives, such as longer-term deposits or wholesale funding. However, both of these options may raise their overall cost of funding, which — if banks seek to maintain their profit margins — could prompt banks to increase the cost of the credit they provide to the economy. In turn, that could result in a lower volume of lending by banks, all else being equal.

If disintermediation were to occur on a large scale, that would either imply a large fall in lending or would require banks to seek to borrow significantly more from the Bank of England. This could have profound implications for the structure of the banking system and the Bank's balance sheet.

(1) Other models and implementations of CBDC are possible, but would have their own economic consequences that depended on their design and are not discussed here.

(2) See also Broadbent (2016), Mancini-Griffoli *et al* (2018), Andolfatto (2018), Kumhof and Noone (2018), Meaning *et al* (2018), and Chiu *et al* (2019), among others.

(3) A corollary of higher deposit funding costs would be higher rates of return for depositors.

Box 4

The balance sheet impact of a switch from cash or deposits to CBDC

Switching from cash to CBDC: Banknotes and CBDC are just two different types of central bank liability, so a switch from banknotes to CBDC affects the composition — but not the size — of household and central bank balance sheets. The household swaps one asset (cash) for another asset (CBDC) and the central bank swaps one liability (cash) for another liability (CBDC). Although banks may facilitate this conversion from cash to CBDC, the process has no impact on the size of the banking sector's balance sheet.

Switching from deposits to CBDC: A shift from deposits into CBDC has the same impact on bank balance sheets as a withdrawal of banknotes from an ATM or bank branch, reducing both the assets and liabilities of the bank and shrinking the bank's balance sheet. This means that net shifts from deposits to CBDC (partially) disintermediate the banking sector. For example, if a household wants to convert £10 of deposits to CBDC:

- The household tells its bank to make a £10 payment from its deposit account to its CBDC account (in effect, 'withdrawing' CBDC just like with cash).
 - The bank debits (ie reduces the value of) the household's account by £10.
- The bank tells the central bank to transfer £10 from its reserves account to the household's CBDC account.
 - The central bank debits (reduces the value of) the bank's reserves account, and credits (increases the value of) the household's CBDC account, by £10.
- The composition of the household's assets changes, because it now holds £10 less in deposits and £10 more in CBDC. But there is no change in the overall size of the household's balance sheet.
- The composition of the central bank's liabilities changes: it now has £10 less in reserve liabilities and £10 more in CBDC liabilities. But there is no immediate change in the size of the central bank's balance sheet.
- However, the commercial bank has lost both £10 of reserves (an asset) and £10 of deposits (a liability). Its balance sheet has contracted by £10.

A flow from deposits to CBDC results in commercial banks as a whole holding fewer reserves. If they end up holding fewer reserves than they need to meet their own or supervisory liquidity risk measures, they may wish to acquire more reserves from the central bank. If the central bank chooses to meet this demand by issuing new reserves, then the central bank's balance sheet will expand by the amount of newly issued reserves.

These potential costs of disintermediation mean it is important to design CBDC in a way that makes the demand for CBDC, *vis-à-vis* bank deposits, manageable. However, gauging the likely shift from deposits into CBDC is challenging because to date no major economy central bank has introduced a CBDC. Important lessons can be learned from previous financial reforms in the UK that have had implications for bank intermediation,⁽⁴⁾ but significant further research is needed.

5.3 The impact of CBDC on the Bank's monetary and financial stability objectives

Impact on monetary policy

By acting as an additional, digital alternative to bank deposits, CBDC could mean that any changes in Bank Rate would be passed on faster and more fully to the rates faced by households and companies (Meaning *et al* (2018)).

(4) For instance, both Competition and Credit Control in 1971 and the financial liberalisation reforms of the 1980s had large effects on the demand for bank deposits and bank lending and major implications for monetary and financial policy at the time.

However, if CBDC became more attractive relative to deposits, the extent of disintermediation of the banking sector would likely be greater. An associated reduction in the availability, and/or an increase in the cost, of credit from the banking sector would be likely to have important consequences for both aggregate supply and demand in the economy. Any fall in the total amount of bank lending would also lessen the importance of bank lending in the overall transmission of monetary policy, meaning that other channels of transmission would become relatively more important.

A shift from deposits to CBDC could result in banks drawing down on their stock of reserves (which must be paid across to CBDC accounts). Banks may need to replace some of these reserves, for example to meet their own risk appetite or regulatory liquidity requirements. While the stock of reserves is currently ample in the UK as a result of quantitative easing, this may not always be the case. In 2018, the Bank explained that, once it begins to unwind quantitative easing, it intends to meet banks' demand for reserves by lending at Bank Rate against high-quality collateral.⁽⁵⁾ However, a large-scale shift into CBDC may mean that banks would not have sufficient amounts of the right quality collateral to obtain the reserves they need. Aside from the financial stability implications of a shortage of liquid assets, this could result in market rates moving out of alignment with the policy rate, or necessitate adjustments to the Bank's monetary policy implementation framework — including to consider supplying reserves against a wider range of collateral. Given this, the design of CBDC would have to consider the effects on how the Bank implements monetary policy.

Impact on financial stability

As discussed in Chapter 2, a well-designed CBDC could have the potential to enhance financial stability by supporting a resilient payment system and averting some of the risks of new forms of privately created money.

First, if a universally accessible payment system such as CBDC were to be established and actively used, it could reduce systemic risk by providing some core payment services that are outside of, and not reliant on, the banking system. Second, disintermediation of the banking sector is already happening as a result of developments in payments. CBDC could give the Bank more opportunity to manage these risks and, depending on its design parameters, may not result in greater disintermediation than is expected regardless of the introduction of CBDC.

But CBDC could also introduce risks for financial stability, offsetting some of these benefits. In a transition to CBDC, the shrinking of banks' balance sheets could affect the availability of credit, which may have an impact on financial stability. While over time the banking system would be expected to find a new equilibrium, a rapid flow into CBDC from bank deposits (from a single bank or from multiple banks) could be destabilising. If, during a period of stress or financial uncertainty, households and businesses saw CBDC as less risky than commercial bank deposits (notwithstanding that retail depositors enjoy FSCS protections), that rush to safety could trigger broader systemic instability. In that sense, a period of rapid substitution from deposits to CBDC would be equivalent to a run on the banking system. This could in principle happen today through a run from deposits to cash, but runs to cash are limited by the practical frictions and costs involved in withdrawing and storing large amounts of cash. In contrast, the cost and frictions of running to CBDC would likely be much lower (although this would depend on its final design). This may incentivise banks to take steps to protect themselves, for instance through a tendency to 'hoard' reserves in a period of stress. That behaviour would impact further on the functioning of money markets.

However, the Bank would still be able to use its existing macro and microprudential tools, including its ability to supply reserves and liquidity to the system, to limit the incentive for runs to CBDC in the first place.⁽⁶⁾

In the most extreme scenario, where a CBDC fully replaced transactional sight deposits at commercial banks, those banks — if they were not to reduce lending — would be reliant entirely on other sources of funding. To the extent that this included an increased reliance on existing central bank facilities, or if shortages of private market funding prompted central banks to adjust the extent to which funding is offered, this would have significant implications for the role of the central bank, including in influencing the cost of credit. Any expansion of the central bank balance sheet to support bank funding would raise the question of what assets would match the additional liabilities, and how they would be supplied. In this scenario there may be a shortage of high-quality

(5) Bank of England (2018).

(6) Villaverde *et al* (2020).

assets to back an enlarged central bank balance sheet, and therefore the central bank may have to broaden the range of assets purchased or lent against.

5.4 Managing the risks through economic design of CBDC

Three possible tools to manage these risks, discussed below, are remuneration of CBDC, the tiering and structure of that remuneration, and limits on the amount of CBDC that could be held.

While the central bank would have direct control over these economic design choices, it would have to be aware that it might have only indirect control of features offered by Payment Interface Providers that could also affect the final attractiveness of CBDC. For instance, user-friendly design, loyalty schemes or other financial products being bundled with CBDC could make holding CBDC more attractive to the public.

Design choice 1: Remuneration

The most important design decision for CBDC would be whether to remunerate, ie pay interest on CBDC balances. A CBDC could be unremunerated (non-interest bearing) like banknotes, or remunerated (interest bearing) like central bank reserves, bank deposits and many other financial assets. In stable economic conditions, the rate of remuneration would be a key determinant of how attractive CBDC would be relative to other forms of money, how widely it would be adopted, the extent of any disintermediation it might cause, and how it might impact monetary and financial stability.

Unremunerated CBDC

An unremunerated CBDC would essentially be a digital version of banknotes. While potentially an attractive risk-free form of money and a useful means of payment, there would be less incentive, relative to a remunerated option, for households and business to make a significant movement away from bank deposits (at least beyond balances they currently hold for payments-related purposes). There would also be a lower impact on the banking system's ability to provide credit. However, in the current low interest rate environment the interest paid on bank deposits might not be sufficient to disincentivise moves to an unremunerated CBDC.

An unremunerated CBDC would not directly transmit changes in Bank Rate to holders, nor would it be likely to have large effects on money market interest rates. But an unremunerated CBDC could still have important implications for monetary policy. In particular, it could reinforce the lower bound on interest rates. The lower bound exists because if interest rates fell significantly below zero depositors could withdraw and hold banknotes. But doing so comes with some costs, particularly for large amounts, because banknotes must be stored securely and cannot be used for payments that are not face-to-face. This makes the effective return on cash holdings slightly negative and has enabled some central banks to set policy rates below the zero rate paid on cash. CBDC would probably have negligible storage costs, making it easier to hold unremunerated CBDC when other interest rates drop below zero, significantly reducing the extent to which rates could go into negative territory. Although the Bank's current assessment is that the lower bound is slightly above zero, due to the structure of the financial system, this assessment could change in the future as the financial system evolves.

How would this be different for a remunerated CBDC?

Remuneration could have a number of implications for the monetary transmission mechanism. A remunerated CBDC, which would be a closer substitute for bank deposits, could lead to faster and fuller transmission of monetary policy to deposit rates. The rate paid on a remunerated CBDC would set the lower limit of the return households and businesses were prepared to accept on their money holdings. This may mean that as the rate paid on CBDC varied, banks might adjust the deposit rates offered to households and companies to avoid a change in the relative attractiveness of CBDC to deposits. A remunerated CBDC would also mean the public received interest on their CBDC balances. This would increase the proportion of money linked directly to monetary policy choices, and have an impact on the monetary transmission mechanism. As interest rates changed, the effect on the interest income received by deposit and CBDC holders would be more pronounced (an effect known as the 'cash-flow' channel). Ultimately, the impact would depend on the relative changes to interest rates on both saving and borrowing.

On the other hand, remuneration increases the potential for greater disintermediation of the banking system by increasing the incentive for households and businesses to shift larger amounts of money into CBDC. Households' deposits tend to be relatively 'sticky', ie they tend to stay with one bank, meaning that households and businesses may continue to hold their sight deposits at banks even if a remunerated CBDC were introduced. Other attractions to holding deposits, such as overdrafts and the associated benefits of a banking relationship, may also limit conversion to CBDC.⁽⁷⁾ But the stickiness of deposits may change with or without the introduction of CBDC, as initiatives such as Open Banking and the Second Payment Services Directive (PSD2) (see Annex) make it easier for users to switch, and move money between, bank accounts in the UK.

There may also be benefits from remuneration for unconventional monetary policy. If interest rates are, and continue to be, low then central banks are likely to be constrained by the lower bound more frequently than historically was the case.⁽⁸⁾ A CBDC that could be remunerated at a *negative* rate could be used to relax that constraint, to the extent that the constraint was caused by the fact that cash pays zero interest (Bordo and Levin (2019)). This could, theoretically, widen the policy options available and avoid the economic costs of having monetary policy hit the effective lower bound, potentially improving economic outcomes. However, the wider effect of setting a negative interest rate on CBDC could be limited if cash use remains prevalent in the economy and cash storage costs are not excessive. And for this benefit to be realised the issues related to the structure of the financial system, which determine the current effective lower bound for Bank Rate, would need to have changed.

Design choice 2: Structure and tiering of remuneration

If the Bank were to decide to remunerate CBDC, but was worried about the impact on bank intermediation and credit, it might be possible to alter the *structure* of any possible remuneration in addition to setting the headline interest rate. For instance, it need not pay the same rate of interest on CBDC as is paid on the reserves held by banks (Bank Rate), as was implicitly assumed above. The CBDC rate could be set lower than Bank Rate, which would allow deposit rates to go some way below Bank Rate.

Alternatively, if policymakers intended CBDC to be used primarily for transactions, rather than as a large-scale store of value, remuneration could be *tiered* such that balances above a certain level pay a lower interest rate or no interest at all (Bindseil (2020)). The Bank could also introduce the potential for remuneration by initially 'remunerating' CBDC at zero but leaving open the possibility of applying a non-zero interest rate in the future.

Design choice 3: Limits

To address the concern that CBDC could lead to a degree of deposit outflow from the banking sector and into CBDC, the central bank may also wish to impose some limits on the amount that could be held by each individual or business. Setting aside the practicalities of this, limits on individual holdings of CBDC could help ensure that CBDC was used primarily for payments balances and not for large savings, reducing the extent of disintermediation of the banking system.

A *hard* limit would specify the total amount of CBDC that each type of user could hold (perhaps with a different limit for businesses and individuals). Such a limit would pose some practical challenges. For example, if a user reached its CBDC limit, would incoming payments to that account be blocked? In addition, if users could hold multiple CBDC accounts with multiple Payment Interface Providers, there would need to be a way to calculate each user's total CBDC holdings across all accounts. This would not be impossible, but would require careful technological design.

If CBDC were to be remunerated, then soft limits, such as the tiered remuneration schedule discussed above, may be preferable to hard limits. Soft limits could provide an economic incentive for users to limit their holdings of CBDC by making it less attractive to hold balances above a given level.

(7) Chiu and Hill (2015).

(8) Carney (2020).

If CBDC were introduced, limits could also be used as a precautionary tool for an initial period. The central bank would be able to observe demand for CBDC and its determinants, and could over time gradually change limits based on experience.

Another form of restriction would be to limit the rate of conversion by limiting maximum transfers over a certain time period. This could be done either by requiring a notice period for large amounts, or by imposing a ceiling on individuals' daily transfers.

More research and analysis is needed on the viability of limits, and the trade-offs between limiting the speed of possible bank runs to CBDC and reducing the usefulness of CBDC in normal times.

6 Technology design

Key points

- The technology used to power CBDC should be chosen on the basis of our design principles. There are trade-offs between different design principles, so we would have to strike the right balance in order to achieve the Bank's policy objectives.
- We do not presume that CBDC must be built using Distributed Ledger Technology (DLT), and there is no inherent reason it could not be built using more conventional centralised technology. However, some of DLT's individual component innovations may be useful.
- Distribution and decentralisation (as used in DLT) may enhance resilience and availability, but could have a negative impact on aspects such as performance, privacy and security.
- CBDC may be able to provide 'programmable money' through smart contracts. There would be a range of options for how this might be delivered, including: building the functionality into the core ledger; providing the functionality via a separate 'module'; or enabling the functionality to be provided by third parties.
- Cryptography should be used to increase the security of the CBDC platform, but this needs to be carefully designed to avoid having a negative impact on usability or performance.

6.1 Overview

Technology choices would have a bearing on the extent to which CBDC is resilient, secure, fast, efficient, extensible, available and scalable, and so these decisions would be crucial to meeting the overall objectives for CBDC. For this reason, it would be essential to choose a technological approach that best meets these design principles.

This chapter focuses on the core CBDC ledger in the illustrative model described in Chapter 4, which would be operated by the Bank. However, much of the technology in a CBDC system would be provided by Payment Interface Providers, including the software and hardware that powers their own systems, and the interfaces used by users of CBDC.

Although CBDC is often associated with Distributed Ledger Technology (DLT — see Box 5), we do not presume CBDC must be built using DLT. Most existing payment systems are run on centralised technology stacks, and there is no reason CBDC could not also be built this way. However, DLT includes a number of potentially highly useful innovations, which can potentially be adopted independently of each other, allowing us to use the specific features of DLT which are most relevant and appropriate, without using DLT in its entirety. This chapter considers which of those innovations could be useful in a CBDC context.

Box 5

Relevant elements of Distributed Ledger Technology (DLT)

Since the advent of Bitcoin over a decade ago, the term 'DLT' has come to refer to a wide range of technologies, many of which take quite different design choices — as such there is no single implementation of DLT. However, there are several common features of the technology — the core 'building blocks'⁽¹⁾ — which can be deployed to varying degrees in different implementations (Figure 6.1). These building blocks include:

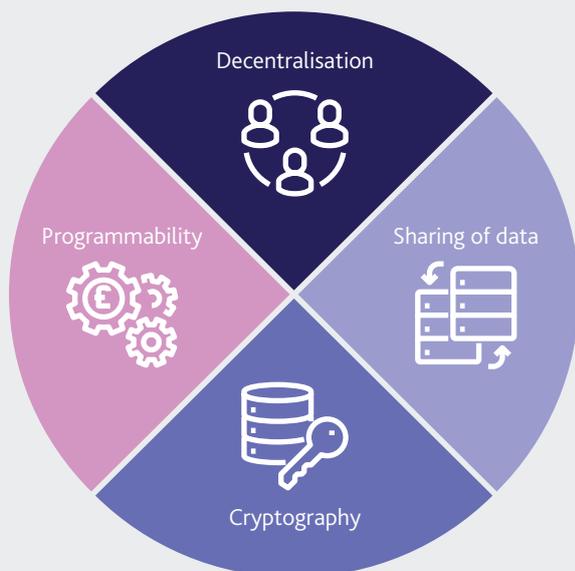
- **Decentralisation:** where a number of third parties are involved in maintaining copies of the ledger and processing updates to the ledger (such as transactions). This requires a 'consensus process' to ensure that all copies of the ledger are synchronised and store the same information.
- **Sharing of data:** visibility of the ledger, including providing access to a wider group of participants to 'read' data on the ledger, and/or the right to update ('write') data on the ledger.
- **Use of cryptography:** the range of cryptographic features which can be used to enable different type of functionality, including the use of public key cryptography to verify that someone sending a payment instruction is entitled to do so, or the use of cryptographic proofs to assert facts about the ledger (eg that a particular transaction has occurred).
- **Programmability:** the creation of so-called 'smart contracts' which can be used to automatically execute terms of an agreement, and initiate related transactions, without human intervention.

These elements can potentially be adopted independently of each other — for example, the programmability features of smart contracts can be deployed over a ledger created using more traditional centralised database technology.

Some important questions in the context of CBDC are (a) which of these elements can helpfully support our objectives for CBDC, and (b) what are the implications and trade-offs of adopting different features?

Figure 6.1 Elements of DLT

Each of these elements can potentially be adopted independently of each other



(1) [Building blocks: the useful elements of blockchain](#), Simon Scorer (2019).

6.2 Our requirements for the core ledger

Any form of CBDC would require a ledger, to keep a record of CBDC transactions, and to maintain the overall stock and supply of CBDC. One reason for this is to prevent users being able to 'double-spend' CBDC by sending the same units to different recipients. There are considerations, discussed later in this chapter, around whether the ledger is centralised or decentralised, and whether it uses an account-based or token-based data structure but, in all of these scenarios, a ledger is required.

The core ledger must be optimised around the following design principles:

- **Resilient:** because CBDC would likely serve as a critical piece of national infrastructure, it would need to be able to handle hardware and software failures in parts of the CBDC system, or telecom network failures, while sustaining continuity of operations and without having a single point of failure that could break the system. It must also be resilient to, and able to adapt to, peaks in demand.
- **Secure:** in particular, CBDC would need to maintain data integrity and be protected from data loss, data theft and cyber vulnerabilities. It must be possible to upgrade the security model as threats evolve.
- **Available:** CBDC payments would need to be available 24/7, and so the core ledger should also operate 24/7, with no planned downtime.
- **Scalable:** it must be possible to increase the capacity of the core ledger as demand increases over time.
- **Fast:** because CBDC would be used for retail payments, the ledger must be able to process and confirm transactions very quickly.
- **Efficient:** the processes should be optimised around the functionality that will be used by most or all users. More complex functionality that would only be used by a smaller subset of users should be left for overlay services, where possible, to avoid adding complexity or reducing the speed of the core ledger.
- **Extensible:** the core ledger would need to be able to provide the necessary functionality to enable a range of overlay services which can meet new use cases and evolving demands. It must be possible to update and upgrade the platform as demand changes.

Building a payment system requires making trade-offs and striking the right balance between different design principles. Consequently, in designing a CBDC it will be impossible to maximise the outcome on every design consideration. For example, some common trade-offs in payment systems include:

- **Transaction throughput versus speed of settlement.** Card payment systems handle high volumes of low value payments, and prioritise the speed of payment authorisation when a customer is standing at the checkout counter, even though the merchant may not receive the funds for a number of days. In contrast, the high-value payment systems used by banks and financial institutions handle lower volumes of payments and prioritise liquidity efficiency and the speed with which the payee receives the funds with no possibility of the payment being reversed (known as 'finality of settlement').
- **Simplicity versus functionality.** In the platform model outlined in Chapter 4, the Bank's core ledger would have the minimum necessary functionality, because limiting the functionality reduces the number of possible flaws, or bugs, in software (boosting the resilience of the system) and limits the 'attack surface' for hostile actors (boosting the security of the system). However, if we limit the core functionality too much, it may limit the ability of Payment Interface Providers to build useful overlay services, thereby limiting the extensibility and level of innovation in the CBDC payment system.

The use case for CBDC in this paper is focused on retail payments (between households and businesses), and so we would need to consider the needs of these groups when prioritising certain design choices.

6.3 Decentralisation and resilience of the core ledger

Many existing technology platforms, including payments, social media, video streaming and search engines, require very high levels of resilience. This is often achieved through the duplication of data and processes. Duplicating data and processes across multiple servers in different locations makes it significantly less likely that the data will ever be lost and ensures that the system as a whole can continue to operate even if part of the system fails or is cut-off from the rest of the network. The same applies to the processing of transactions. The use of these techniques would be an essential part of ensuring that any CBDC core ledger is resilient and available.

Duplication typically involves one entity that controls all of the duplicated components (eg servers, data centres etc), such as the central bank in the case of Real Time Gross Settlement systems. Decentralisation involves going further to involve multiple different entities, such as different companies, in storing copies of the ledger and processing updates to that data (ie transactions). This requires a 'consensus process' to ensure that all copies of the ledger are synchronised and store the same information. In the context of CBDC, it might be possible to involve Payment Interface Providers or other trusted technology providers in the process of maintaining the core ledger, processing transactions and storing data for the CBDC system as a whole, rather than just for their own customers. Alternatively, if multiple central banks provided CBDC, they could possibly partner with each other and operate 'nodes' in each other's CBDC networks.

A decentralised approach could add further resilience to a CBDC system. Differences in geographical locations, and approaches to implementation can create more diversity in the system as a whole, which means that problems that affect one type of hardware, or one software version, are unlikely to affect all parts of the network simultaneously.

However, a decentralised approach also comes with a number of significant trade-offs, including:

- **Performance:** the consensus process in the decentralisation of data requires transmitting a high number of messages between participants for each transaction. As a result, many DLT platforms to date have struggled to match the performance of more 'centralised' payment platforms in respect to aspects such as throughput and speed.
- **Data privacy:** involving third parties in the processing of transactions ('transaction validators') may require the sharing of private data with them. There are approaches to mitigate this, but these come with their own challenges.⁽¹⁾ One approach involves segregating the data so that each individual transaction validator only has visibility of a subset of the ledger. Alternative approaches involve using advanced cryptographic techniques (for example those based on zero-knowledge proofs)⁽²⁾ to hide details, such as the counterparties or the value of the transaction, from the transaction validators. However, these are currently computationally intensive and currently have a negative impact on performance.
- **Security:** involving multiple parties in the operation of the system may provide more targets for potential cyber-attackers, particularly in relation to data theft. However, the use of multi-party consensus could also make a system more secure against attackers that are attempting to manipulate data, for example to steal funds. The overall security of any system as a whole depends on the 'weakest link' – the entity that has the weakest security standards. This may represent a greater challenge if many parties are involved.

Consequently, decentralisation comes with challenges. Systems with no duplication at all will have lower resilience, but systems that are extremely decentralised are likely to be slow, inefficient and difficult to scale. An important area of technology research is to identify the appropriate and optimal level of distribution or decentralisation for the CBDC core ledger, achieving the best combination of resilience, speed, efficiency and scalability.

(1) Stella: *Balancing confidentiality and auditability in a distributed ledger environment*, European Central Bank and Bank of Japan (2020).

(2) A zero-knowledge proof is a cryptographic method which allows one party to prove to another party that they possess certain information, without disclosing the information itself.

Whatever degree of duplication and decentralisation is used, the Bank would need to retain overall control of the CBDC network. This means it would always need to be a 'permissioned' system, with the Bank granting access to the network. It is likely that only regulated Payment Interface Providers would be allowed to connect to the core ledger, a restriction that adds a layer of security to the core ledger. If a DLT approach is used, the Bank could also control which entities are allowed to operate a node in the network (processing transactions for the network as a whole). In all arrangements, the Bank must have exclusive control of the creation (issuance) of new CBDC, and the technology design must ensure that this remains the case.

6.4 Programmable money

One of the most interesting features that has emerged through developments in DLT is the potential to create 'programmable money'. This can be implemented via the use of 'smart contracts' — pieces of code which are able to self-execute payments based on some pre-defined criteria. In simple terms, these contracts are statements that say 'If X happens, then pay Y to Z'. An example would be a forward-dated payment: 'If today's date is X, then transfer £100 from account Y to account Z'. More advanced smart contracts could be used (for example) to automatically initiate payments on the confirmed receipt of goods, or routing tax payments directly to the tax authorities at point of sale. Transactions could also be integrated with physical devices, or the 'Internet of Things', for example code could be written to say 'when £X is transferred to account Y, switch on device Z'.

Smart contract functionality can be (and is being) decoupled from DLT. It is possible to implement smart contracts over a variety of types of ledger, including centralised databases. It is also possible to restrict the range of functionality available within a smart contract programming language, which may be desirable for both security and efficiency reasons.

Smart contracts are more complex to process than a simple push payment, so their use could have a negative impact on performance and scalability.⁽³⁾ Smart contracts may also have a negative impact on the security of the system; significant funds have already been lost or stolen as a result of vulnerabilities in smart contract platforms.⁽⁴⁾

If CBDC were to support programmable money functionality, we see three broad potential approaches: building the functionality into the core ledger; providing the functionality via a separate 'module'; or enabling the functionality to be provided by Payment Interface Providers.

Providing full programmable money functionality on the core ledger would come with significant trade-offs. Requiring the core ledger to perform the more complex computations associated with smart contracts would have an impact on its performance, potentially slowing down individual transactions whether they were associated with a smart contract or not. However, this approach may be necessary to realise the full extent of the benefits associated with programmable money.

An alternative approach would be for the Bank to develop an additional 'module', separate to the core ledger, to manage and process smart contracts. This module would be responsible for processing smart contract code, and would then instruct the core ledger when a payment is needed. This approach could mitigate the negative impact on the performance of the system, while still leveraging the Bank's position as a trusted party. The module would require the appropriate authority to move users' funds, as well as a process for users to control and approve this functionality. This approach would require careful consideration around aspects including the process for user authentication.

A third option is to restrict the smart contract related functionality provided by the Bank to the minimum necessary to enable Payment Interface Providers to provide a more complete range of programmable functionality to users. This minimum functionality might include the ability to cryptographically lock funds in an

(3) In some DLT platforms, high demand to use popular smart contracts has caused the entire network to hit capacity constraints and become congested, for example see [CryptoKitties craze slows down transactions on Ethereum](#), BBC News (2017).

(4) See [Understanding the DAO attack](#), David Siegel (2016).

effective escrow service.⁽⁵⁾ In this approach there would also be a role for the Bank in setting standards for smart contract functionality. These standards would ensure interoperability between providers and set minimum security standards, but would not dictate how the services are provided.

Each of these potential approaches to supporting programmable money functionality would need significant further evaluation, in order to understand the potential advantages and implications, and to determine an optimal approach.

6.5 Security and use of cryptography

The instant nature of CBDC payments means that the system could be an attractive target for hackers or fraudsters who wish to steal funds. In addition, the CBDC payments system may become a target for hostile attacks with the aim of disrupting the system and, potentially, the wider economy. For these reasons, the security of the CBDC payments system must be of the highest standard.

There are two aspects of security that we need to consider in particular: user security and security of the payment infrastructure.

Building user security requires thinking carefully about how payments are initiated, how users are authenticated, and what happens if users lose credentials or private keys (discussed below), or are tricked into making payments to the wrong recipient. A lot of this user security will be handled by Payment Interface Providers themselves, but the Bank would need to set minimum security standards. There may also be a trade-off between user security and the extent to which the platform is user-friendly as a whole, although there are ways to provide a user-friendly interface on the back of a very secure system.

The need for security of the payment infrastructure would apply to the core ledger, the Payment Interface Providers, the overlay services they provide, and the network connecting them. These services would need to be resilient to cyber-attacks and avoid having single points of failure that can be targeted. The system should be able to recover quickly from an attack. The CBDC core ledger and wider network would need to be designed with a security model that can be constantly upgraded to protect against evolving threats.

A common aspect of most DLT platforms is the use of cryptography to validate the accuracy of a copy of the ledger, to lock-up funds for a period of time or until a specified event has happened, or to validate the correct owner of specific funds. Use of cryptography can enhance security, but also comes with some challenges. For example, if private keys are used to authenticate payment instructions, but a user's private key is lost or stolen, the funds may be lost forever. Therefore, high security around the storage of private keys would be required, and a mechanism to 'freeze' and reissue CBDC where the corresponding private key has been lost.

Cryptographic security is constantly evolving, and individual cryptographic functions can weaken over time as technology advances, making them vulnerable to attackers. It would be vital that any cryptographic functions deployed in a CBDC continue to be secure as technology advances; this is likely to require the ability to change and upgrade the specific cryptographic techniques used by the system over time.

6.6 Account-based versus token-based approaches

The literature around CBDC and DLT often discusses 'token'⁽⁶⁾ and 'account' based models, and there are a range of differing interpretations of these terms. The terms are often used as shorthand for a wide range of independent design choices that are not necessarily directly linked to either of these two concepts.

(5) More advanced techniques, such as Hash Time-Locked Contracts (HTLC) have been explored by other central banks as a way of enabling 'atomic' transactions between different ledgers. See Monetary Authority of Singapore, Bank of Canada and JP Morgan (2019) or ECB and BoJ (2018). To enable the use of HTLC, in addition to the ability to lock funds, the ledger would also need to support a timeout mechanism to release the lock, and certain cryptographic features to disclose secret information.

(6) Note that the term 'tokenisation' also has a different meaning in the context of data security. This relates to the process of protecting sensitive data by replacing it with a non-sensitive equivalent, referred to as a 'token'. This process is commonly used in payments, for example to replace a 16-digit card number with a single-use unique token, allowing payments to be processed and the token to be passed through a network, without exposing the actual account details.

In our view, the core difference between token-based and account-based systems relates to the underlying data structure and the related process for moving funds:

- An **account**-based system records the state of the system as a list of accounts, each of which has a corresponding balance. When funds are transferred, the record is updated by increasing and decreasing the balances in the relevant accounts. In order to initiate a transfer, the holder of an account is required to demonstrate their authority to do so, either by proving their identity as the account holder, or providing that they hold some information (eg password or private key) that only the account holder should know.
- By contrast, a **token**-based system records the state of the system as a list of individual assets (or 'tokens'), each of which has a corresponding 'owner' who can control the asset. Each of these tokens has a specific value (eg £15), which does not change. In order to initiate a transfer, the holder of a token is required to prove they control the token, usually by signing a payment instruction with the private key associated with that token. Individual tokens cannot be partially spent — instead, the token being transferred is generally 'destroyed' and replaced with two newly created smaller tokens (with the same total value), with one going to the recipient and the other being returned to the sender as 'change'.

We do not see any inherent reason that token-based systems would automatically provide anonymity. Both account-based systems and token-based systems can be configured with various identity solutions, ranging from fully anonymous to pseudonymous and to a fully transparent, identifiable solution. As discussed (Chapter 4.6), any CBDC would need to be compatible with AML obligations, ruling out truly anonymous payments. In Chapter 4.2 we assume that the core ledger could use pseudonymous accounts (with Payment Interface Providers managing identification), although other models would also be feasible.

In digital form, neither an account-based approach nor a token-based approach would enable cash-like transfers, where a payment can be made without reference to any third party or intermediary. In an account-based system, the accounts of the payer and payee need to be debited and credited by the operator(s) of the ledger. And in a token-based system, in order to prevent double-spending, ownership of tokens needs to be recorded in a ledger, which will need to be updated to reflect any changes in ownership.

So, from an operational perspective, either a token or account-based approach might be able to provide the necessary range of functionality for a CBDC. However, there may be certain use cases or overlay services which are better supported by one of these data structures, and there may also be important legal implications.

7 Next steps and priorities for further research

7.1 Overview

It is clear that the introduction of a Central Bank Digital Currency (CBDC) in the UK would pose both opportunities and challenges for monetary policy, financial stability and payments. Before any decision could be taken on whether to introduce a retail CBDC, the Bank would need to be clear that the net benefit for payments users, the financial system, and society as a whole would outweigh any risks.

The illustrative model of CBDC set out in this paper is intended as a basis for further discussion and research, rather than as a blueprint for a final design of CBDC. Our work so far has highlighted a number of ways that CBDC could be designed to maximise the benefits and mitigate the risks. But there are still many questions that need careful consideration. Our ongoing work on CBDC will focus on the following areas:

- **Impact on payments:** Understanding the benefits that CBDC could provide for payments users and for the economy more widely, taking into account that payments needs are changing as the economy becomes increasingly digital. This includes understanding how CBDC could complement or facilitate other initiatives to improve payments, particularly the significant improvement initiatives currently underway in the UK (see the appendix).
- **Impact on monetary and financial stability:** Quantifying the benefits and implications of CBDC on monetary policy and financial stability, and identifying ways to mitigate any risks. This includes understanding the impact on the Bank's own balance sheet and operations.
- **Functionality and provision of CBDC:** Developing the design of CBDC to maximise benefits and minimise risks, and identifying the appropriate role of the public and private sector.
- **Technology:** Understanding the technology that would be most appropriate to power a CBDC, including how the Bank could build a CBDC that enables significant further innovation in payments.

More detailed questions on each of these areas are listed below. We plan to draw on the widest possible expertise, and we invite ideas and feedback from technology providers, the payments industry, financial institutions, academics, other central banks, and public authorities.

We do not expect written responses to address all questions, and observations on other aspects are also welcome. Details on how to respond can be found on page 6.

7.2 Understanding the impact of CBDC on payments

CBDC poses a number of potential opportunities for improving the payments landscape in the UK, as discussed in Chapter 2.4. However, each of these opportunities also come with challenges that require careful consideration.

- 1 How could CBDC be designed to support a more resilient payments landscape in the UK?
- 2 How could CBDC be designed in a way that improves the efficiency and speed of payments, while also facilitating competition and innovation?
- 3 How could CBDC be designed to meet future payment needs? How might future innovations and evolutions in technology (eg the Internet of Things) change these needs?

- 4 As usage of cash as a means of payment declines, is it important to preserve access to central bank money for households and businesses?
- 5 Does CBDC pose other opportunities or challenges with respect to the payments landscape that we have not discussed?
- 6 What factors would determine the level of adoption of CBDC as a means of payment in the UK?
- 7 Are the design principles described in Chapter 3.2 comprehensive? What are the most significant trade-offs between some of these design principles?

There are significant initiatives underway in the UK to facilitate improvements in both electronic and cash payments. These initiatives are outlined in the appendix. The Bank will continue to fully support these initiatives, recognising the significant benefits they could provide for the UK payments landscape. It is essential to understand how CBDC would work alongside these existing initiatives, and how CBDC fits into the wider payments landscape.

- 8 How could CBDC be designed to complement other public and private sector initiatives to improve payments in the UK?
- 9 Could CBDC provide unique benefits, over and above existing initiatives, to improve UK payments?
- 10 Could the potential benefits of CBDC alternatively be achieved with policy levers to (a) influence the private sector to deliver a better payments landscape, or (b) address market failures or co-ordination problems in the private sector?
- 11 Could the potential benefits of CBDC be alternatively achieved by enabling new innovative private sector arrangements (eg stablecoins) to develop?

7.3 Understanding the impact of CBDC on monetary and financial stability

As discussed in Chapter 5, CBDC could impact the structure of the banking system and the way that the Bank achieves its primary objectives to maintain monetary and financial stability. It is important to fully understand these impacts, and ways to mitigate any risks through the design of CBDC.

- 12 What opportunities could CBDC provide to enhance monetary or financial stability?
- 13 How much demand would there be to hold CBDC? How would that demand vary depending on the economic design choices outlined in this paper?
- 14 To what extent might CBDC lead to disintermediation of the banking system? How would the degree of disintermediation vary with different economic, functional and technological design options outlined in this paper? How would different degrees of disintermediation affect the stability of banks and the rest of the financial system?
- 15 How would CBDC affect the monetary transmission mechanism and policy setting under existing monetary policy frameworks? What overarching analytical frameworks could be used for modelling how CBDC would affect the macroeconomy and monetary policy?
- 16 What are the most significant risks to monetary policy implementation, and how could those risks be addressed?
- 17 How could CBDC affect the portfolio of unconventional monetary policy tools available to the central bank? How effective would a remunerated CBDC be in relaxing the effective lower bound on monetary policy?

18 How would increasing the efficiency of payment systems affect the macroeconomy and monetary policy?

7.4 Functionality and provision of CBDC

In the platform model of CBDC, presented in Chapter 4, the Bank would build a fast, highly secure, and resilient technology platform — the 'core ledger' — which would provide the minimum necessary functionality for CBDC payments. This would serve as the platform to which private sector firms, called Payment Interface Providers, could connect in order to provide customer-facing CBDC payment services.

- 19 What are the advantages and disadvantages of this public-private payments platform approach? What alternative approaches might be considered?
- 20 Are there viable business models that would incentivise firms to offer CBDC-related payment services in this approach?
- 21 What are the respective advantages or disadvantages of (a) the pooled accounts model described in Chapter 4.2, and (b) the alternative approach described in Box 3 in Chapter 4?

In the platform model, Payment Interface Providers would build 'overlay services' — additional functionality that is not part of the Bank's core ledger, but which could be provided as a value-added service for their users.

- 22 What kind of overlay services would be most useful? What functionality would a CBDC core ledger need to provide to enable these?
- 23 How could CBDC be designed to ensure businesses are able to easily accept CBDC payments at the point of sale?
- 24 What would be needed to ensure that CBDC would be inclusive and accessible by all sectors of society in the UK?
- 25 What is the appropriate privacy model for CBDC? Is it necessary, or feasible, to replicate any of the privacy aspects of cash?
- 26 Would offline payments functionality be required in CBDC?

7.5 Technology, infrastructure and further innovation

As discussed in Chapter 6, the technology used to power CBDC should be chosen on the basis of what best meets our design principles. It will therefore be necessary to understand the potential of a range of different technologies, and the trade-offs each of these presents.

- 27 The paper describes a core ledger, operated by the Bank, which supports a range of Payment Interface Providers through an API layer. What are the advantages and disadvantages of this architecture? What are the alternative architectures that we should consider?
- 28 What are the main trade-offs that arise in deciding on a technology approach? What should we be prioritising in these trade-offs?
- 29 The core ledger for this model of CBDC could be centralised, or operated through a consensus-driven distributed approach. Which is the optimum approach, and why?
- 30 What are the merits, or challenges, of either 'token-based' or 'account-based' approaches to a CBDC ledger? Are there particular use cases that are better supported by either approach? Are there alternative approaches?

- 31 What are the key use-cases for programmable money?
- 32 What architecture choices would best support programmable money functionality in a CBDC? Would it be preferable to build this functionality into the core ledger, via a separate module, or to enable the functionality to be provided by third parties? Are there alternative approaches?
- 33 How could CBDC support offline functionality? Are there technology solutions that can enable this without exposing any party to credit risk?
- 34 What dependencies would CBDC have on other innovations, such as digital identity solutions?
- 35 What other future technology and digital economy innovations should we be factoring into the potential design of CBDC? How might these impact the future demands placed on CBDC, and potential approaches to designing a CBDC?

Appendix: UK initiatives to improve payments

In Chapter 2 we set out a number of areas in which CBDC could potentially offer improvements to UK payments. This appendix describes some existing initiatives in the UK that will also contribute to improvements in these areas.

Joint Authorities Cash Strategy Group and the Wholesale Distribution Working Group

In the UK, the Access to Cash Review (commissioned by ATM network LINK) concluded that the UK is not yet ready to go cashless (Access to Cash Review (2018)). It set out five recommendations, which call for: more co-ordinated regulation and oversight of the whole cash system; a new wholesale cash infrastructure; a guarantee that the public will be able to access cash services; that cash remains widely accepted; and that digital payments are an option for everyone (Access to Cash Review (2019)). The first two of these recommendations are directly relevant to the Bank's responsibilities on cash.

The Bank's formal responsibilities with respect to cash are: it is the sole issuer of banknotes in England and Wales; it delivers effective protection for holders of Scottish and Northern Ireland banknotes; and it oversees how banknotes are then distributed to the wholesale market (for example, entities such as banks and the Post Office). Therefore, in 2019 the Bank convened relevant industry stakeholders to develop a new system for wholesale cash distribution that is efficient, resilient and sustainable, including in a world with lower cash volumes.

To ensure access to cash, the public needs to be able to withdraw and deposit cash. Given the shared responsibilities in this area, the Joint Authorities Cash Strategy Group was created. It has brought together HM Treasury (as chair), the Payments Systems Regulator, the Financial Conduct Authority and the Bank, with the objective of supporting access to cash for those who need it.

Open Banking and PSD2

Open Banking and PSD2⁽¹⁾ require banks and other payment service providers to share customer financial transactional data with authorised third parties in a standardised way (ie through APIs), with customer consent. This is designed to increase competition in the banking sector, and enable third parties to innovate and create new financial products. Furthermore, customers have the ability to authorise these third parties to automatically initiate payments on their behalf. Examples of innovation enabled by these directives include the emergence of financial aggregators (which allow customers to view their account information from different providers through a single interface, making it easier for customers to compare products from different providers), personal financial managers (which provide insights on customer spending and in some cases provide financial advice), and services to support SME financial management (allowing the automation of functions such as invoicing, tracking payments and managing payslips).

RTGS renewal

The Bank, as operator of the sterling Real-Time Gross Settlement (RTGS) service, is seeking to promote innovation in payments by expanding access to settlement in central bank money and through renewing RTGS. This could reduce the cost of on-boarding as a direct participant in domestic payment systems.⁽²⁾ In 2017 the Bank announced that Electronic Money Issuers (EMIs) and payment institutions authorised by the FCA could start applying for RTGS settlement accounts.⁽³⁾ To date, around half a dozen firms have joined and others are in the pipeline.⁽⁴⁾

(1) Open Banking is a directive issued by the Competition and Markets Authority (CMA) that came into force in January 2018. PSD2 is EU's Revised Payment Services Directive.

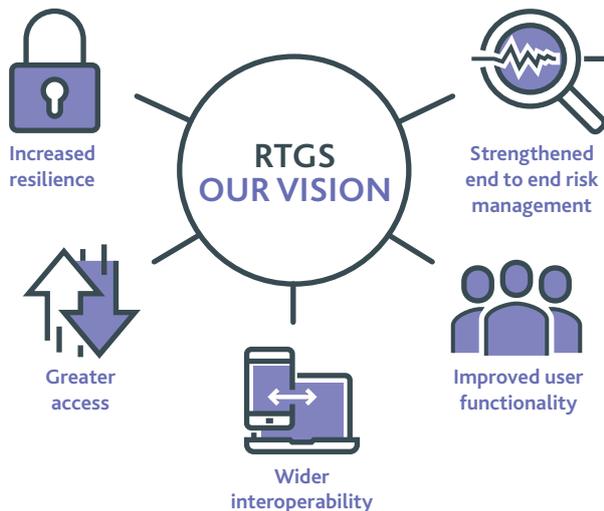
(2) See [RTGS Renewal Programme](#) and [A blueprint for a new RTGS service for the United Kingdom](#), Bank of England (2017).

(3) Settlement accounts allow firms to offer settlement in central bank money directly to their clients, rather than over the books of a bank. They are intraday accounts and need to be funded at the beginning of the day and defunded at the end of the day.

(4) [Access to UK payment schemes for non-bank payment service providers](#), Bank of England, FCA and Pay.UK (2019).

The programme to deliver a renewed RTGS aims to enhance resilience and promote innovation. The service will offer a range of new features and capabilities for payments and settlements between financial institutions. The vision is to develop an RTGS service which is fit for the future. This means increasing resilience and access, and offering wider interoperability, improved user functionality and strengthened end-to-end risk management of the UK's High Value Payment System. The first major milestone will be the move to ISO 20022 messaging in 2022, followed by the transition to a new core ledger in 2023.

Figure A.1 Our vision for the new RTGS service



By developing a RTGS service with features such as a flexible and modular architecture, near-24/7 operating capacity and an API layer to support automated data transfer, the Bank is seeking to ensure it can accommodate and facilitate the emergence of new business models in payments.⁽⁵⁾

There are new settlement systems emerging (such as Fnality), proposing to issue digital settlement tokens that would be fully backed by central bank money, allowing instant settlement. The Bank aims to publish proposals on how, and under what conditions, new settlement providers could open accounts at the Bank to facilitate similar innovative wholesale settlement models.

Balance Sheet Access Review

The Bank's response to the 'Future of Finance' report committed to 'consult in 2020 on the appropriate level of access to the Bank's payments infrastructure and balance sheet, including necessary safeguards'. Our focus is on whether, and how, to give non-bank payments service providers (NBPSPs) the ability to hold deposits at the Bank overnight. It is critical that access supports fully the stability and resilience of the system while also allowing innovation in payments.

Pay.UK's New Payments Architecture

In 2018 the operators of the main UK retail payment schemes — Bacs, FPS and Cheques — were consolidated into Pay.UK. Pay.UK are now developing the 'New Payments Architecture' (NPA) that will replace the existing interbank retail payment systems with an aim to develop world-leading infrastructure that supports instant settlement with a view to ending multiple-day clearing cycles (in Bacs and cheque clearing) and ensuring fast and resilient 24/7 clearing. The goal is to establish a system that is easy to access, easy to upgrade and innovate on, and able to provide new capabilities that payment service providers (including banks) can exploit for their customers' benefit. Successful delivery of the NPA will provide a highly resilient and instant payment system for interbank payments.

(5) [A new messaging standard for UK payments: ISO 20022](#), Bank of England (2020).

HMT Payments Review

At Mansion House the Chancellor announced a Treasury-led review of the payments landscape that brings together policymakers and regulators to ensure that regulation and infrastructure keeps pace with new payment models. The review aims to investigate what the UK needs to do to remove barriers and support a more resilient and innovative payments system with more diversity of payments methods. This includes the methods available to make payments and the services and systems that facilitate this. The objectives include action to explore if amendments are needed to 'future-proof' the regulatory approach for changes in the payments landscape.

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