Central bank digital currencies: system design and interoperability

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Contents

CBDCs would exist in interoperable systems where the multiple roles and responsibilities would need to be coherent and support policy goals. This report outlines the considerations for central banks in designing systems that benefit from private-public collaboration and interoperability. Doing so highlights the importance of payment data and privacy in driving choices on infrastructure architecture, messaging standards and the role of a central bank. The next steps for this work will be to review the impact of financial stability safeguards and user requirements on system designs.

1. Introduction and general overview

This report explores central banks' considerations for designing a potential general purpose (retail) central bank digital currency (CBDC) system. This includes an overview of the potential functions in a broad ecosystem, the different possible roles in a private-public collaboration, how interoperability could be a core feature and a central bank's options in how an interoperable CBDC system could be implemented.

Key messages:

- **The central banks contributing to this report anticipate any CBDC ecosystems would involve the public and private sectors in a balance to deliver the desired policy outcomes and enable innovation that meets users' evolving payment needs**. Depending on the priority motivations for a CBDC, there would be multiple considerations involved in allocating roles individually and collectively, requiring extensive dialogue with users and stakeholders. Yet a theme that cuts through almost every consideration is interoperability. Domestic interoperability would be key to ensuring a CBDC system coexists with other national payment systems and contributes to broader accessibility, resilience and diversity.
- **For CBDC systems, domestic interoperability would need to be sufficient to achieve an easy flow of funds to and from other payment systems and arrangements**. Central banks would have options in how they achieve interoperability, from use of established messaging, data and other technical standards to building technical interfaces to communicate with other systems. Yet barriers to interoperability would likely exist, covering technical, commercial and legal aspects. Dialogue with stakeholders would be key in addressing these.
- **Regardless of the design, developing and running a CBDC system would be a major undertaking for a central bank**. Operating CBDC ecosystem functions would be a significant undertaking and any outsourced functions would need to be carefully managed to deliver public trust in a CBDC system. Likewise, individual and collective oversight of those functions and services provided or operated by private intermediaries would be required.
- **Access to and treatment of payment data would play a significant role in any ecosystem design**. Privacy considerations could create a series of other design and interoperability challenges, ranging from the messaging standards used, how to create incentives for diverse intermediaries to offer services and how to interoperate with traditional systems that require detailed account and transaction information.
- Further exploration will further review the practicalities of interoperability with existing payment systems; while also considering how financial stability safeguards and user requirements (including privacy) might influence the design of a CBDC system that enhances monetary and financial stability, co-exists with robust private money and offers users an innovative and efficient means of payment.

Section 2 sketches the elements, functions and possible roles in CBDC systems as well as considerations for central banks. Section 3 then narrows its focus to interoperability, including a technical introduction, options and considerations. Section 4 concludes and outlines possible next steps.

2. System design

- A CBDC ecosystem would comprise multiple elements and functions. A core ledger with supporting infrastructure and rules would underpin a broader ecosystem of processing infrastructure, processing providers and user services with business and technical rules.
- The central banks contributing to this report anticipate ecosystem functions divided among the public and private sectors in a balance that delivers the desired policy outcome.
- To deliver that outcome, a central bank would have to consider the motivations or goals driving the implementation of CBDC. Yet, in any CBDC system, the central bank would face additional operational or oversight tasks and accompanying challenges regardless of the division of responsibilities among the various actors.

2.1 Elements outlined

A CBDC system would likely comprise similar elements and underlying functions as traditional payment systems, with central banks facing many of the practical policy questions around access, services and structure that they do today (CPSS (2003)). Payment systems comprise an operator and participants as well as the instruments, procedures, and rules for transferring funds (CPMI-IOSCO (2012)). Beyond this "core" system, a broader ecosystem includes end users and technical processing and supporting infrastructure providers as well as contextual legal, supervisory and contractual arrangements exist. These elements and functions are set out in Table 1.

At the centre of any CBDC ecosystem would be a CBDC core rulebook outlining the legal basis, governance, risk management, access and other requirements of participants in the CBDC system. Supporting these rules would be a core technical infrastructure operating a core ledger allowing a central bank to issue, redeem and settle CBDC as well as potential other activities.[1]

Participants in the CBDC system would act as intermediaries between the central bank and end users. Intermediaries could include banks, payment service providers, mobile operators and fintech or big tech companies depending on the access policies set out in the core rulebook. Each use case would follow its own business and technical rules depending on the participants and processing infrastructure involved. These rules would determine how different use cases work, including (eg) initiation, processing, fees and compensations, use of data and data protection. These could include how offline payments are processed and corresponding risks are managed outside the CBDC ledger (all within the scope of any broader requirements set out in the CBDC scheme rules).

Intermediaries would use one or several processing infrastructures enabling payment messages to be processed, reconciled and to access and communicate with the core infrastructure.[2] The intermediaries could be responsible for payment services including: (i) pre-transaction (eg on-boarding, providing access devices and channels); (ii) transactions (eg customer service and support); and (iii) post-transaction (eg advice, statements and billing).[3] Intermediaries would also include the operators of the processing infrastructures as well as the providers of processing services. This broader ecosystem would

[1] For example, monitoring or implementing remuneration and centralised controls and safeguards.

[2] A processing infrastructure could be owned and operated by the intermediary itself or another entity (eg a payment processor). The processing infrastructure could perform (eg) pre-checks (limit checks, funds availability), authentication, authorisation, verification or validation (manage exceptions, restore and correct incorrect transactions, handle offline authorisation limits, biometrics), screening (security and regulatory checks), interaction between intermediaries and between intermediaries/CB, reporting and statistics.

[3] An access device or channel provider could be someone other than an intermediary, eg a point-of-sale terminal provider or a software provider.

be complemented by a legal and supervisory framework and contractual arrangements between end users and their intermediaries. For users and intermediaries to understand this broad ecosystem, a central bank would need to communicate clearly (Box 1).

Elements, functions and roles in a CBDC ecosystem Table 1

Element	Possible functions	Role considerations
Core system		
Core rulebook	The core principles of CBDC transactions/use, outlining the legal basis, governance, risk management, access and other requirements of participants.	The central bank could be a sole operator and/or a broader governance arrangement could include public or industry governance bodies.
Core infrastructure	Issuing, redeeming and settling CBDC on the CBDC ledger and potentially monitoring, safeguard or remuneration implementation.	Issuing and redeeming CBDC would be a core central bank function. Yet some activities could be outsourced and supervised by the central bank.
Broader ecosystem		
Processing Infrastructure	Message preparation, processing and reconciliation Communication with core infrastructure Connectivity with enabling functions (eg digital identity systems, underlying telecoms networks)	A variety of processing infrastructure options could add choice and competition for users but also create complexity. A single processing infrastructure run by the central bank or outsourced to a third party could provide a level playing field for payment and processing service providers.
Processing Services	Payment pre-checks (eg limit checks, funds availability) Authorisation, verification or validation (eg managing exceptions, restoring and correcting transactions, handling offline authorisation limits) Screening (eg security and regulatory checks) Data and analytical services	To encourage innovation and efficiency, a variety and combination of private providers (eg banks, payment service providers, non-bank processors, technology companies, and other entities) could run processing services enabling their own payment services, or those of others.
Payment Services (interaction with end users)	Pre-transaction (eg access device or channel, on-boarding of users) Transaction (eg payment instruction, authentication, customer service and support) Post-transaction (eg payment advice statements and billing)	To encourage innovation and efficiency, a variety and combination of private providers (eg banks, payment service providers) could run payments services and provide user support.
Use case arrangements	A set of business and technical rules determining how a use case works	Responsibilities could fall with the central bank and/or industry governance bodies.

Box 1

"Accounts" and "tokens" in CBDC systems

Many CBDC system design discussions initially drew a distinction between "account-based" and "token-based" CBDCs in the context of how it would be used as a means of payment (CPMI-MC (2018)). However, since the terms "token" and "account" can be used to demarcate different concepts across different fields, there has subsequently been differing usage and interpretations of these terms. For example, "token" is sometimes used in economic literature as shorthand for designs where CBDC has one or more cash-like features (such as representing a bearer instrument and supporting offline or anonymous payments). Elsewhere, in computer science literature, "token" can instead refer to digital access keys or to representations of assets on blockchains.

Central banks engaging in public dialogue and consultation on CBDC would want to avoid confusion, so the terms "token" and "account" may therefore require additional explanation in any communications. For example, "account-based" might be used to refer to a CBDC system where payment involves updating payer and payee balances whereas "token-based" could be used to refer to a system where a record is updated for who holds a particular CBDC representation. Yet as digital systems, these would both require a ledger ie neither would replicate cash-like transfers. Both CBDC systems could also use various means to identify users ie in either approach, payments could be anonymous, pseudonymous or fully identifiable. Finally, these two approaches are technology-agnostic ie they could be implemented based on traditional technology or a distributed-ledger.

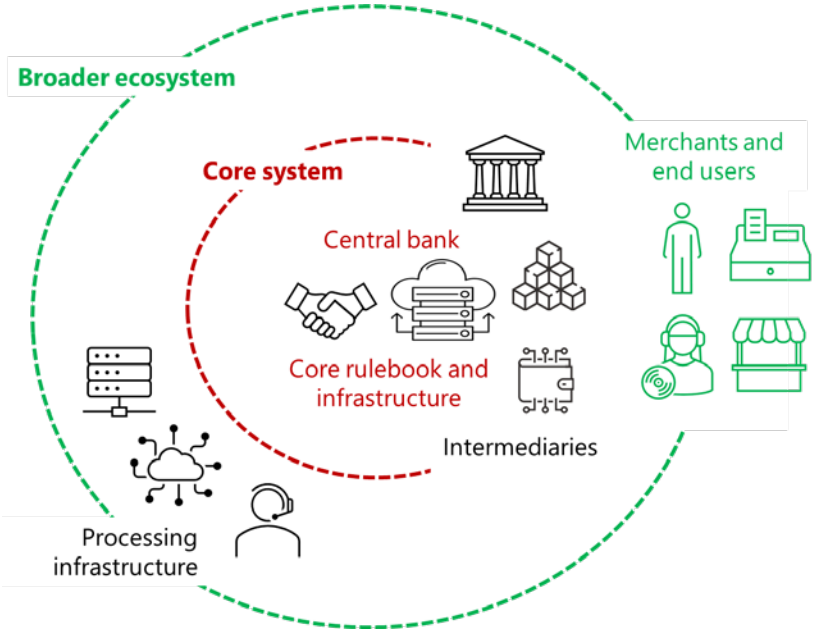
2.2 Possible roles

The functions outlined above could (in most cases) be carried out by different actors of the public or private sector. Central banks would be the only entities entitled to issue and redeem a CBDC and would bear the ultimate responsibility for the design of the CBDC system and the operation/oversight of the core ledger. Therefore, assigning the roles within a CBDC system would likely be the prerogative of a central bank – including the roles it would play as an operator (running a function internally), outsourcer (maintaining responsibility for a function but contracting a specialist provider) or overseer (not performing the function but ensuring that it was carried out effectively and diligently).

Theoretically, a central bank could perform all the functions in an ecosystem, either through directly operating or outsourcing certain functions. For example, a "direct" CBDC system (Auer and Böhme (2020)) could resemble government or post office banking services (Grym (2020)). However, central banks lack experience in customer service and established networks of physical and digital contact points for customers. In the case of a CBDC purely operated by a central bank (potentially with some outsourced elements), everything would need to be set up and (arguably more importantly) maintained and updated, to support users' developing digital payment needs. Although likely unsuitable for the central banks contributing to this report, for jurisdictions lacking adequate private payment provision for the public, a direct system could be appropriate.

The central banks contributing to this report envisage CBDC ecosystems based on a broad public-private collaboration, ie a "tiered" system where some roles would be carried out by the public sector and others by private entities. In an effective system, each actor would collaboratively play the role they are best suited for. Public entities have public policy goals, private entities have shareholders and market-driven goals. A natural split in any tiered CBDC system would be for the central bank to be responsible for the core of the system to the extent that they could steer the system to deliver policy goals and a safe and efficient payment system. Multiple private entities would then act as intermediaries, competing and offering choice within an ecosystem to drive innovation and efficiency (Uchida (2021)). The functions and possible roles are outlined in Table 1 and illustrated in Graph 1.

Illustrated elements, functions and roles in a CBDC ecosystem Graph 1



2.3 Considerations

A central bank would face a significant number of considerations in assigning the functions within an ecosystem. Each function would bring its own unique considerations (eg the entities best placed to carry it out given their incentives and/or technical ability) and fit into a broader consideration (eg how choices fit together to meet the policy objectives for the system).

System designs would likely differ between jurisdictions as central banks make choices that best suit their circumstances. These include motivations previously outlined by central banks, including: (i) continued access to central bank money, (ii) resilience, (iii) increased payments diversity, (iv) encouraging financial inclusion, (v) improving cross-border payments (vi) supporting privacy and (vii) facilitating fiscal transfers (Group of central banks (2020)). Different elements and functions differ in importance across each motivation and bring different broader considerations for a central bank allocating roles.

2.3.1 Additional access to central bank money

To provide additional access to central bank money for the public, a CBDC ecosystem would need to closely define the payment use cases it wants to support (Group of Central Banks (2021b)), including elements applicable to financial inclusion (discussed in 2.3.4 below).

Depending on how broad the use cases in a CBDC ecosystem were, a larger public sector and central bank role in providing services to end users may be required to achieve universal access to central bank money (these considerations are similar to those for financial inclusion, discussed in 2.3.4 below). For some use cases, a central bank could play an operational role beyond the core system, eg through providing processing infrastructure, services and services to end users. Where there were a lack of interest or incentive for private participation in roles beyond the core system, or certain use cases, a central bank or other public body could also consider providing these themselves.

If the central bank were to play too operational or dominant a role in the ecosystem, private intermediary participation could be curtailed with a reduction in the diversity, innovation and efficiency of the system (potentially also giving rise to legal or constitutional questions). To avoid negative outcomes while still maintaining access to central bank money, interoperability with other systems and convertibility with other types of robust private money would be necessary.

2.3.2 Resilience

Enhancing a jurisdiction's broader operational resilience could be achieved through a CBDC system acting as an additional payment method. A CBDC system itself would need to be resilient to technical failure, counterfeiting and cyber risks. And such a system, operated solely by the central bank, with elements independent of pre-existing payment infrastructure, could continue to operate if those other systems fail. Designing a system in this way would, however, be a significant undertaking and the resilience benefits would need to be assessed against the costs in the broader context of the resilience of existing domestic payment systems.

All technical elements of a CBDC ecosystem would need a high level of operational and cyber resilience. And depending on technical designs, the core infrastructure may have to have an even higher standard. Beyond the core system, the broader ecosystem could share processing infrastructure with other payment systems. Yet if this failed or was compromised, it could undermine both system's availability at the same time. Building parallel processing infrastructure to duplicate functionality could add resilience but also costs to users, merchants and intermediaries (potentially even undermining convertibility between a CBDC and other types of money). And finally, to act as an additional payment method if another system failed, a CBDC system would need to be interoperable or substitutable for that system and use cases.

Beyond incorporating stand-alone elements, a CBDC system could also introduce a higher standard of business continuity or cyber resilience for intermediaries providing payment or processing services. However, private intermediaries may not internalise all broader negative impacts from an operational incident (ie they may be likely to invest less in business continuity than is systemically optimal) (CPMI (2018b)). Requirements would need to be set and overseen to ensure high standards. Yet high requirements may also raise costs for intermediaries, reducing competition and innovation.

2.3.3 Increased payments diversity

Payment systems, like other infrastructure, benefit from strong network effects, potentially leading to concentration and/or fragmentation. A CBDC system could avoid these private "winner takes all" networks achieving a monopoly through providing/demanding interoperability between them (Cœuré, (2020)).

In a tiered CBDC ecosystem, the more diverse the private intermediaries were, the more likely there would be overlapping system or network memberships, creating competition, choice for users and efficiency in the system. This would be true for intermediaries in payment services but also potentially for payment processing too (eg where competition between private payment processors were limited, this could erode the opportunities for payment service intermediaries who rely on them).

However, a broad range of intermediaries may also lead to unclear responsibilities, a higher likelihood of failures (operational or financial) and user disruption. Approval processes for new intermediaries or certain services and strong oversight could help mitigate this (although the costs of oversight would increase with the number and diversity of intermediaries).

2.3.4 Financial inclusion

Increasing digitalisation could create financial inclusion issues as barriers around trust, digital literacy, access to IT and data privacy concerns create a digital divide (barriers also applicable to continuing to provide access to central bank money, discussed in 2.3.1 above).

Private payment services intermediaries naturally have an incentive to cater to users likely to generate the most profit. Therefore, an ecosystem in which the public could only access CBDC through private intermediaries might struggle to achieve universal access or services for all relevant use cases. To overcome this, a central bank or other public body (eg a post office or government bank) could offer services, legislation requiring basic access could be proposed and/or incentives for private intermediaries to supply otherwise underserved end users could be introduced.[4]

However, as for any financial inclusion initiative, a broader strategy to tackle the causes of exclusion may be required to realise results. For example, a CBDC would be unlikely to represent a "complete package" of financial services, therefore interoperability with other private savings products, government services or digital identification may be beneficial.

2.3.5 Improving cross-border payments

CBDC systems, through starting with a "clean slate", could reduce some of the frictions in current cross-border payments through interoperating across borders (CPMI (2021)). However, a CBDC would be no different to a traditional payment system in that broader compatibility requirements like consistent technical standards, oversight frameworks, private and public laws and requirements for anti-money laundering and counter terrorism financing, would still be necessary for effective interoperability (Auer et al (2021)). Yet international collaboration, specifically through the G20 "roadmap" to enhance cross-border payments, is actively working on these issues to improve existing payments and CBDC systems of the future (FSB (2020)).

2.3.6 Supporting privacy

Supporting privacy could be a key motivation for CBDC issuance (Box 2). Yet full anonymity is not plausible, as central banks would design CBDC systems to meet anti-money laundering and combating the financing of terrorism requirements (along with any other regulatory expectations or disclosure laws) (Group of central banks (2020)).

The CBDC system design would determine which actors have access to what information. This would include models where a central bank outsources the operation of parts of the core or processing infrastructure. The central bank would have no commercial interest in end-user data and may be better placed than a commercial entity to commit to a minimal use of such data outside payment processing, eg the use of anonymised and consolidated data for macro-economic policy related analysis or use for a system backup.[5] Yet concentration of end-user data may nonetheless raise concerns among the public, even if privacy safeguards were in place. Beyond the central bank, end-user identities could be stored by intermediaries, subject to the rules imposed in the system. These rules would need to be transparent, understood across the ecosystem and flexible enough to respond to developing data regulation in jurisdictions.

Considerations for a central bank regarding privacy include intermediaries' business models and innovation, interoperability and other motivations. Data is rapidly becoming an important part of private sector business models. Higher levels of privacy and restrictions beyond those required by the jurisdiction's data regulation may negatively impact intermediaries' revenue streams and their ability to add new innovative products, potentially reducing the diversity of participants in the system. For interoperability, where other systems require personal information to settle payments, there could be challenges in implementation. Finally, other motivations like use for fiscal transfers or integration in wider governmental systems would require users to share their "CBDC address" with public authorities other than the central

[4] In Europe, legislation has been introduced to create general access to transaction accounts with basic payment functions at banks. An equivalent approach for CBDC services could also be considered.

[5] For example, Auer and Böhme (2021) envisage a CBDC with "hybrid architecture" where the central bank would retain a copy of all user CBDC holdings, allowing it to act as technical backstop to the system.

bank. Digital identity systems could play an important role, yet financial inclusion and universal access to central bank money motivations (including the possibility for use by foreign travellers) could require other identification means even where a digital identity was in place.

Box 2

Privacy and data in CBDC systems

Privacy is an acknowledged fundamental human right in most international instruments, such as the United Nations Declaration of Human Rights (Article 12). In payment systems, privacy requirements can protect against business models that abuse individual data, resulting in unfair business practices like exclusion or discrimination. Requirements can also protect against malfeasance or negligence by counterparties or the operator of a system and against unsubstantiated or unreasonable government surveillance. The ECB's recent public consultation on the requirements of a digital euro shows that privacy was considered the most important feature, subject to restrictions to avoid illicit activities (ECB (2021)).

Restrictions to avoid illicit activities would require the design of a CBDC to consider anti-money laundering and counter financing of terrorism risks (AML and CFT). Financial Action Task Force (FATF) recommendations covering cash or electronic payments could apply to CBDC yet could also bring hurdles in protecting privacy for users. For example, the so-called "travel rule" (FATF (2021)) requires participants' transaction data to be collected and shared along a payment chain (hence "travel"). Outside these requirements, collecting and processing personal data is also subject to country-specific data protection regulations.

In this context, central banks would face three questions regarding privacy: (i) what data is to be protected; (ii) from whom is it to be protected, and (iii) to what degree is it to be protected? Data to be protected could include personal information about the payer or payee or information about the payment itself. Information about the payment could reveal personal information about the payee (eg wealth when buying luxury items or health issues when buying medicine), their relationships or business. This would likely be especially revealing when combined with corroborating data sets. Privacy could be protected from the payment parties (at least with respect to their identities), against the issuer of the money, the payment/network providers/processors, the regulator/supervisor, the government, or other third parties. Regarding the degree of data protection, information could be kept anonymous, pseudonymous, or confidential. For example, anonymous payments would contain no data to identify parties,① pseudonymous payments would contain data that cannot be linked to the identities of the parties and confidential payments would identify the parties but only to a narrow set of recipients. The transparency of the data to these recipients could also be defined further.

Existing retail payment system designs (eg those supporting cards or credit transfers) exchanging originator and beneficiary information at every step in the payment chain could struggle to offer the level of privacy required for a CBDC system without redesign. Central banks face two challenges in this context: (i) building a system with potentially different architecture to support privacy and then (ii) interoperating with existing systems that require personal information to settle payments.

However, new developments in cryptography such as "zero-knowledge proofs", blind signatures, private decentralized networks, offline smartcards and the use of "layered" data management in payment systems are promising and could offer ways to enable a high degree of privacy whilst complying with existing AML and CFT standards. However, not all of them have been subjected to due cryptographic auditing, let alone stood the test of time. Implementing these techniques in CBDC may therefore require a significantly longer timeline.

① Although for a CBDC, full anonymity is not plausible (Group of central banks (2020)).

2.3.7 Facilitating fiscal transfers

A central bank motivated to build a system to better enable fiscal transfers (eg the government assistance payments from some governments seen in the recent Covid-19 pandemic) would need to overcome identifying the recipients of any payments. A system in which the central bank (eg) operated some of the payment processing infrastructure and had complete information about user identities, accounts and balances would make this simple. Yet it would also raise significant privacy concerns (outlined above).

Interoperability with a digital identity system could allay some of these concerns and accommodate a broader tiered system.

3 Interoperability

- Interoperability is a broad term. For a CBDC system, it would encompass characteristics sufficient to achieve an easy flow of funds to and from other payment systems. This would help ensure the coexistence of a CBDC system within a wider payment ecosystem.
- Central banks have options in how they could achieve interoperability, from use of established messaging standards, data and other technical standards, to building technical interfaces to communicate with other systems.
- Significant domestic and international consultation and dialogue to understand the practical impact of any choices would likely be required, both prior to launch and during the life of any CBDC system.

3.1 Interoperability explained

Interoperability is a broad term, potentially incorporating any characteristic of systems that enable payment systems to exchange information.[6] For a CBDC system, sufficient interoperability to ensure an easy flow of funds between payment systems would be a "core feature" and would contribute to the coexistence of a CBDC within a wider payment system (Group of central banks (2020)). This would include a range of characteristics from accommodative technical infrastructure to common legal and regulatory frameworks and data and messaging standards. The essential foundation of interoperability would be "standardisation", which would allow compatibility (Bank of Japan (2021)).

Interoperability between payment systems contributes to achieving adoption, co-existence, innovation and efficiency for end users.[7] It would be key to integrating a CBDC into the broader payments landscape of a jurisdiction and thereby drive end user adoption (both for the public and merchants). Where payment systems fail to interoperate, there is a risk of fragmentation and "closed loop systems" that create risks and user costs from a lack of competition (CPMI (2018a)). As outlined in the considerations for system design above, interoperability would directly or indirectly support most payment motivations for CBDC issuance.

Cross-border and cross-currency payments are inherently more complex than domestic ones (CPMI (2018a)). Interoperability between cross-border CBDC systems would likely face additional challenges and a broader range of considerations than those explored here. However, significant international work is currently underway to improve current and future cross-border payments (CPMI (2021)). The main frictions identified to cross-border payments are high costs, limited access, low speed and limited transparency (CPMI (2020)) and interoperability could help to address these frictions. The central banks contributing to this report are also active participants in this work.

[6] The International Organization for Standardization (ISO) defines interoperability as the "capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units" (ISO (2015)).

[7] Also referred to as "horizontal" interoperability compared to "vertical" interoperability, which is concerned with characteristics that aid integration within a single system.

3.2 Options

Interoperability would be a core feature of any CBDC system and central banks would have options in how it was achieved.

At a basic level, interoperability would involve standards. For payment systems, these would include a range of technical specifications, operational requirements and legal or supervisory accreditation. Standards would include messaging and data (ie how a payment message and the data it includes would be formatted and structured), security (ie the cyber and endpoint security requirements) and others (eg operational processing and opening hour requirements or supervisory obligations). Common standards would allow a reduction of frictions and barriers, arguably necessary for the success of any infrastructure interoperability measure such as an interlinkage or technical interface (Bech et al (2020)). Potential options for CBDC infrastructure interoperability include sharing functions (eg using the same authorisation and clearing providers or using the same digital identity scheme), incorporating settlement (eg one system settling in another) or completely shared processing infrastructure and services outside the CBDC core system.

In all likely CBDC system designs, payments would involve multiple stages, as outlined in the functions described in the previous section. Across stages, including the initiating, authorising, processing and settling payments, different characteristics would be more relevant. Common standards could enhance interoperability across these functions. For example, consistent data standards could reduce costs for intermediaries and enable simpler and more effective implementation of technical interfaces (eg common digital identity schemes could enable more efficient initiation and authorisation and consistent messaging standards could allow simpler clearing and settlement). Likewise, consistent encryption and security standards between systems would allow for greater technical integration.

3.3 Considerations

Deciding on the best way to make a system interoperable would bring a significant number of considerations. As system designs and use cases would differ across jurisdictions, the manner, and degree of interoperability would also differ.

In a domestic context, the characteristics of pre-existing payment systems would likely play a significant role in a CBDC's interoperability. For example, if common technical interfaces and data or messaging standards already existed, adopting these could reduce costs. Yet a CBDC could also be introduced with an explicit policy goal to catalyse a migration of national standards to (eg) an internationally promoted standard. To understand the practical implications of any choices, central banks would likely undertake public and technical consultation, with end-users and providers of payments services. Central banks might also need to consider potential barriers to interoperability in their jurisdictions arising from legal or regulatory issues, technological compatibility and commercial interests (Box 3).

Box 3

Interoperability benefits and barriers in CBDC systems

The Great Baltimore Fire in 1904 destroyed buildings across 140 acres of the city. Fire engines from nearby rushed to help extinguish the blaze but were unable to help, as their fire hose couplings did not fit Baltimore's fire hydrants. In response, national standards in firefighting equipment, ensuring interoperability between hoses and hydrants, were put in place (Cochrane (1966)). Payment system interoperability is arguably less dramatic but is based on the same conceptual foundation – the basis of interoperability is common standards.

Interoperability would be a core feature of a CBDC and would be necessary for integrating into a broader payments landscape and achieving public policy objectives. Interoperability could promote competition between payment service providers, create the conditions for innovation and enhance the operational resilience of a broader national payment ecosystem. Failing to achieve interoperability would risk fragmentation of the payment landscape into closed loops, leading to users and merchants facing costs from multiple memberships of systems with frictions impairing the speed and cost of payments. This would be inconvenient for end-users and socially inefficient.

Effective interoperability would also be key to ensure that CBDC would be an appealing proposition for end-users. It could enable smoother user on-boarding, cashing in and out of CBDC, making payments across systems, "sweeping" (eg where businesses would invest their funds overnight) and integration of CBDC wallets with other devices, services and technology. Without achieving interoperability, CBDCs may struggle to achieve the adoption required to be effective (discussed in Group of central banks (2020b)).

Although interoperability would bring significant benefits, its practical implementation could be difficult and may involve trade-offs and compromise. Barriers would relate to technical, commercial and legal issues. Technical barriers could include: inconsistent standards for message formats, data elements, numbering and coding systems, security protocols, scalability or throughput capacity and opening hours. Avoiding these barriers could involve, respectively: using of common (international) technical standards and/or application programming interfaces; requiring minimally viable security standards or encouraging other systems to adopt stronger security; engaging in early and frequent communication with other systems to estimate volumes and throughput; and establishing rules for CBDC payments initiated during the closing hours of other systems. A broad forum of relevant stakeholders could agree a CBDC's technical specifications and coordinate interoperability issues.

Commercial barriers could include an unwillingness of other systems and/or participants to use the CBDC to protect revenues from existing systems. In response a central bank could incentivise participation in the CBDC ecosystem and engage in early outreach. Lowering costs by avoiding the technical interoperability barriers above could also help.

Legal/regulatory domestic barriers could include differences arising from participant supervisory regimes and compliance requirements as well as settlement finality and consumer protection rules in payment systems. Specifically, if there were different supervisory requirements between a CBDC and other payment systems then there could be insufficient overlap to ensure a smooth flow of funds (assuming a more technical interface were not implemented). Similarly, if know-your-customer, anti-money laundering and counter terrorism financing requirements were higher or differed from existing payment systems, this could add costs to participants. For payment systems, rules on the finality of settlement and consumer protection could differ (eg where one system was net settlement and another was gross settlement and procedures in the event of transaction errors, delays, fraud, theft, or insolvency differed). As for other barriers, early engagement and dialogue would be essential to avoiding issues, in this context, with other public authorities tasked with bank and/or payment service provider supervision, the providers themselves and other payment systems.

4 Concluding thoughts and next steps

Designing an interoperable CBDC system, allocating roles and striking the right balance between the responsibilities of the central bank, the public sector and the private sector would be complex. Many of these complexities would arise from coexisting with a jurisdiction's current payments systems while providing a novel, innovative and efficient service for users. Both would be necessary conditions for the success of a CBDC and would likely change with time. The pace of change in private payments arrangements is increasing (BIS (2021)) and consumer expectations for what constitutes innovative, efficient and convenient payments are not static either.

Any CBDC ecosystem would need to be flexible to accommodate future user demands and interoperate with new and existing systems and arrangements while at the same time safeguarding policy goals and system resilience. Therefore, when allocating roles across a system, a central bank would need the power to change the system, either through how it operates or through using oversight powers. In any CBDC system the central bank would play an important role and would have to allocate resource accordingly. Operating any ecosystem functions would be a significant undertaking and any outsourced functions would need to be carefully managed to ensure resilience and public trust in CBDC as a public good.

To keep up with these changes in a highly technical and practical capacity, central banks issuing CBDCs may need to broaden their skills (Carstens (2020)). And supporting these efforts, a central bank's involvement in private-public payments fora may need to significantly increase. The fora themselves may also need to adapt to incorporate a broader range of issues. For example, personal data governance, with its potentially significant impact on interoperability, user confidence and participant business models, may require central banks to engage in extensive dialogue with a broader set of stakeholders outside the traditional payment ecosystem.

Interoperable system designs would be significantly influenced by idiosyncratic domestic circumstances. This would also be true for the user demands and necessary safeguards that would drive the desirability and policy viability of a CBDC (Group of central banks (2021a and 2021b)). The next steps for this work will include reviewing the practicalities of interoperability with existing payment systems. It will also consider how financial stability safeguards and user requirements (including privacy) might influence the design of a CBDC system that enhances monetary and financial stability, co-exists with robust private money and offers users an innovative and efficient means of payment.

Glossary

Central bank digital currency is a digital form of central bank money that is different from balances in traditional reserve or settlement accounts ie a digital payment instrument, denominated in the national unit of account (Group of central banks (2020)).

Payment systems are sets of instruments, procedures, and rules for the transfer of funds between or among participants; the system includes the participants and the entity operating the arrangement. A payment system is a financial market infrastructure (CPMI-IOSCO (2012)).

Payment arrangements refer to any network of participants who collaborate to send and receive payments. These can include payment systems but also networks without a formal operator, overarching agreement or a rulebook (eg correspondent banking arrangements or multi-CBDC arrangements (Auer et al (2021)).

Interoperability is the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units (ISO (2015)) and the technical or legal compatibility that enables a system or mechanism to be used in conjunction with other systems or mechanisms without imposing unnecessary costs on the users (CPSS (2007)).

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Central bank digital currencies: user needs and adoption

September 2021

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in a series of
collaborations from a
group of central banks

Bank of Canada
European Central Bank
Bank of Japan
Sveriges Riksbank
Swiss National Bank
Bank of England
Board of Governors Federal Reserve System
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Contents

If potential central bank digital currencies (CBDCs) are to achieve their policy goals, they would need to be adopted by users and accepted by merchants. This report outlines the considerations for central banks in designing a CBDC that might fulfil user needs both now and in the future. Learning from past payment innovations, considering the features most valued by users, investigating incentives for adoption and carrying out consultations could all play an important role in CBDC design. The next steps for this work will be to continue research on the impact user requirements and financial stability safeguards on system design, and the range of approaches to public engagement and consultation on CBDC.

1. Introduction and general overview

A central bank digital currency (CBDC) would need to be adopted and used if it is to fulfil public policy goals that motivate its issuance.[1] Integral to achieving adoption and use of a general purpose CBDC in a jurisdiction would be understanding and serving current and future user needs in a fast-changing payments landscape. This report examines what drives user adoption of digital payment services, referencing the use-cases and design choices envisaged for CBDC. Without being prescriptive or precise about a specific level of adoption that might ensure success of a CBDC project, this report presents issues that jurisdictions may wish to consider in their own evaluations.

Key messages:

- **CBDC adoption would likely be driven by its future usefulness to users and acceptance by merchants**. Central bank money is the safest form of money available. Yet beyond security, other valuable features of CBDC could include lower cost to consumers and merchants, offline payments, a higher level of privacy in comparison to commercial options and multiple accessibility features.
- **A CBDC would need to anticipate the needs of future users and incorporate related innovations**. Central banks might accommodate evolving user needs by designing a flexible core system, supporting a diverse ecosystem of intermediaries delivering choice, competition and innovation. As payments become increasingly integrated into digital living, a CBDC available to innovators could combine innovative features into a single product in a new and unique way.
- **Strategies for CBDC adoption would need to be tailored to the diverse economic structures and payment landscapes in individual jurisdictions**, but experience points to some common factors. Specifically, adoption may be more successful if it fulfilled unmet user needs, achieved network effects, and were implemented with the use of existing, accessible technology and infrastructure (eg at the point of sale). Additional measures that some jurisdictions might consider for a potential CBDC adoption strategy include the use of CBDC by public sector authorities, requiring some minimum level of acceptance and supporting future payment needs. Not all strategies would be desirable in all jurisdictions.
- **A CBDC adoption strategy in a fast-changing payments landscape would require balancing the needs of the majority of consumers with reaching smaller parts of the population**. Different users and needs would need to be defined and addressed in the system's design. The analysis of specific market segments through user personas and stories could provide an important method for investigating user needs and designing informative consultations with prospective end-users.

[1] Central bank digital currency is a digital form of central bank money that is different from balances in traditional reserve or settlement accounts ie a digital payment instrument, denominated in the national unit of account (Group of central banks (2020)).

- Further exploration will involve considering how financial stability safeguards might allow the CBDC adoption needed to meet public policy objectives and user needs, how user requirements could impact system designs, and the approach to public consultation and communications on CBDC

Section 2 provides some context on CBDC adoption. Section 3 then identifies key features of the experience with implementation of previous payments innovations (both successful and failed) and the lessons that may be drawn for CBDC. Section 4 then examines user needs followed by a discussion on strategies for designing a CBDC. The last section concludes.

2. Context on CBDC adoption

For a discussion of CBDC adoption, there are two important contextual elements from the preceding report published by this group of central banks and the BIS (Group of central banks (2020)).

First, for the central banks contributing to this report, the common motivation for exploring a general purpose CBDC is its use as a means of payment. "Use" in this report should be understood in this context. Adoption of CBDC as a means of payment would likely present the most value for public policy objectives.

Second, without continued innovation and competition to drive efficiency in a jurisdiction's payment system, users may adopt other, less safe instruments or currencies, potentially leading to economic and consumer harm. If user needs emerge in the future, unserved by safe payment instruments, the chance of this risk materialising arguably increases.

CBDCs that support innovation and competition may play a role in supporting future user requirements for payment services. Digital payments are already rapidly changing in response to an increasing integration into evolving digital services (BIS (2020)). It is likely that these evolutions will continue and catalyse an even broader diversity of novel use cases and payments requirements than today. Central banks may therefore need to consider current and possible future user demands in their CBDC system designs, understanding where new technologies might be harnessed (eg programmable money) and through encouraging innovation and competition among intermediaries, while incorporating sufficient flexibility to evolve with digital economies (Group of central banks (2021b)).

Finally, there are broader considerations for central banks arising from user "take-up" of CBDC (ie the use of CBDC as a means of payment and potentially a store-of-value). The speed of user take-up and the potential need for transition arrangements as well as other potential safeguards are beyond the scope of this report but are necessary issues for central banks to consider in designing a potential CBDC that enhances monetary and financial stability (Group of central banks (2021a)).

3. Lessons for CBDC adoption

- Strategies for adoption would need to be tailored to the diverse economic structures and payment landscapes of individual jurisdictions, but experience points to some common factors that are relevant across jurisdictions.
- CBDC adoption may be more successful if it fulfilled unmet user needs, achieved network effects, and were implemented with the use of existing, accessible, technology and infrastructure (eg at the point of sale).

Technological innovation has been transforming the markets for retail payments at pace over recent years, with many new payment methods, platforms and interfaces evolving to become faster, cheaper and safer. These new non-financial market players have shown a strong understanding of what users need from their payments products and what conditions are necessary to facilitate adoption. Central banks would need to take into account this evolving context if they choose to launch a CBDC.

Users' needs and the strategies for ensuring successful CBDC adoption would vary from jurisdiction to jurisdiction, reflecting different economic structures, varied forms of economic activity as well as diverse payments landscapes. However, there is also significant common ground to build on. Reviewing experience with both successful and failed payments initiatives (Box 1) is a first step to identify possible lessons for CBDC implementation and adoption. Although not all of the lessons from private sector payment methods may carry over to CBDCs, which would be issued by the public sector, such lessons are nevertheless useful to understand broader questions about success factors and design choices in novel payment methods.

Experience from previous implementation of payments innovations suggests three factors that might make CBDC adoption successful. These factors are consistent with the wider literature on payment innovation and implementation.[2]

Fulfils unmet user needs. CBDCs would offer, in digital form, the unique advantages of central bank money: settlement finality, liquidity and integrity (BIS 2021). In addition, it would be important for CBDC to meet consumer or merchant demand that might not currently be met by existing payments products and services (see Section 3). Part of meeting these needs would be through encouraging private innovation in CBDC ecosystems (Group of central banks (2021b)). To better meet future payments needs, CBDCs might be integrated into the broader services of private intermediaries.

Achieves network effects. CBDCs might aim to achieve network efforts by targeting one-sided market segments. Consumers would only use CBDC if there were merchants willing to accept it, but merchants would only accept CBDC if there were sufficient consumers who want to use it. Any central bank introducing a CBDC would need to think carefully about how to take account of such network effects. Research indicates that payment mechanisms may be more successfully adopted in a one-sided market like the person-to-person (P2P) payments market (Van der Heijden (2002) and BIS (2012)). CBDC design might therefore choose to emphasize 'peer to peer' (P2P) functionality in order to facilitate adoption. Once used for P2P payments, merchants may then have greater incentives to accept CBDC. Interoperability could also play a role in reducing frictions to user and merchant adoption (Group of central banks (2021b)).

Does not require all users to buy new devices. If a CBDC built on technology already in use, users may be more able to easily set up the account, service, app, or device they would use to hold a CBDC, and merchants may be more able to accept CBDC. However, some users, especially those without smartphones and bank accounts, may require additional hardware. In these scenarios, it may become more important for merchants to integrate CBDC into their existing payment infrastructure. If some merchants had older technology and could not add CBDC payment functionality through new software, CBDC payments might potentially be enabled through the existing infrastructures and networks. This approach might lead to near-instant adoption by the majority of merchants, using systems already integrated with their existing accounting and point of sale (PoS) systems. However, this approach would also build in a reliance on existing networks and infrastructures, with potential negative impacts on resilience and competition.

[2] Mallat (2007) identifies the lack of other payment methods as a critical factor in the user acceptance of mobile payments. Au and Kauffman (2007) point to unmet demand as facilitating successful innovations. Gowrisankaran and Stavins (2004) suggest that pricing below marginal costs is necessary to overcome network externalities. Van der Heijden (2002) identifies both pricing and ease of use as critical factors for consumer acceptance. Shin (2009) presents evidence that in addition to the perceived usefulness and ease of use, users' attitudes towards mobile payment solutions are influenced by perceived security and trust.

Box 1

Lessons from past adoption of payment services

Long-term CBDC adoption would likely depend on the benefits of using CBDC outweighing the costs. Yet there are many examples of products that failed to become widely adopted despite long-term benefits clearly outweighing the costs – pointing to the significance of short-term frictions or barriers to initial use of any CBDC. These might include a time-consuming process for opening an account, difficulty in finding places where CBDC could be spent or, for merchants, the need to invest in new hardware. Case studies of successful and unsuccessful implementations of new payment methods, services, or instruments emphasise the importance of providing the right incentives and reducing potential frictions.

Mobile money initiatives showcase many successful implementations. **Swish**① is a mobile phone app launched in 2012 in Sweden and used by about 80% of the population. While initially only instant P2P transfers were offered, services have expanded to online and point-of-sale payments (with QR codes). Key success factors include an initial focus on a market where no convenient digital alternative existed, easy onboarding and a strong push from banks to encourage their customers' use (to reduce the use of cash). Similar applications in Denmark (***MobilePay***②) and Norway (***Vipps***③) have had comparable success. Elsewhere, **M-Pesa**④ is a mobile money platform launched in 2007 in Kenya and used by more than 95% of the population. Based on short-message-service (SMS) technology, the platform provides the unbanked population access to basic banking-like services. Similarly to Swish, key success factors appears to be that it offered a service in a market where no convenient digital alternative existed and that onboarding was easy.

Yet not all mobile payment services have been successful. **Paybox**⑤ offered a mobile phone payment platform in Germany in 2000. Similarly to Swish, Paybox intended to facilitate payments between bank accounts. Yet insufficient advantages over established systems, high costs for users and a lack of cooperation to encourage customer use meant that adoption never managed to achieve a sustainable level.

Beyond mobile payments, some consider **DigiCash Inc**⑥ from the early 1990s to be the world's first digital currency. Yet by 1998 it was bankrupt, having failed to see significant adoption. Working against its success were: (i) consumers not valuing its unique selling point (anonymous payments); (ii) banks hesitant to enable the service for their account holders as existing card-based electronic payments were lucrative; and (iii) a lack of partnerships with existing customer bases. Also in the early 1990s, the **Avant smart card system**⑦ was introduced by the Bank of Finland. A digital version of cash but based on (at the time) cutting edge smart card technology, the system also provided anonymity but achieved wide acceptance. After three years in operation, the Bank of Finland sold the system to commercial banks. Yet when debit cards upgraded with technology like that in Avant, it was shut down. Decline followed merchants' unwillingness to support multiple payments hardware (for Avant and debit cards), a related loss of acceptance for stored funds and a loss of advantage over other payment alternatives (or even a disadvantage, as loss of a stored value card resulted in a loss of funds).

Finally, beyond domestic services, new cross currency transfers, like **Wise**⑧ and **Revolut**⑨, have grown in recent years. Successful companies typically compete with traditional service providers on price and speed while also provide easy onboarding via mobile phone apps.

① https://www.swish.co.zm/; ② https://mobilepay.dk/; ③ https://www.vipps.no/; ④ https://m-pesa.org/;⑤ Ondrus et al (2015); ⑥ https://en.wikipedia.org/wiki/DigiCash; ⑦ Grim et al (2017); ⑧ https://wise.com/; ⑨ https://www.revolut.com/en-US

4. Users' needs and strategies for adoption

- A CBDC would need to support users' payment needs. In an increasingly digital economy, the assessment of user needs would need to be forward looking and take account of both present and possible future demands of users.
- CBDC adoption would likely be driven by its future usefulness to users and acceptance by merchants. Central bank money is the safest form of money available. Yet beyond security, other valuable features of CBDC could include lower costs for consumers and merchants, offline payments, a higher level of privacy in comparison to commercial options and multiple accessibility features. As payments become increasingly integrated into digital living, a CBDC available to innovators could combine innovative features into a single product in a new and unique way.
- Payments are a two-sided market: The use of a new service depends both on consumer adoption and merchant acceptance.
- Additional measures that some jurisdictions might consider for a potential CBDC adoption strategy include the use of CBDC by public sector authorities and imposing some minimum level of acceptance. Not all strategies would be desirable in all jurisdictions.

The core features of any CBDC instrument and its underlying system include ease of use[3], low cost, convertibility, instant settlement, continuous availability and a high degree of security, resilience, flexibility and safety (Group of central banks (2020)). Central banks, through their current payment systems, already promote interoperability, support competition and innovation, and operate public infrastructures - all essential for easily accessible, low-cost and high-quality payment services (BIS (2020)). In addition, CBDC could offer the unique features of central bank money in digital form relative to other forms of money: settlement finality, liquidity and integrity (BIS (2021)). In this way, a CBDC could combine features to form a unique product.

Several central banks contributing to this report have already engaged in public consultations and other methodologies to understand in more depth the payment attributes that could be valued by consumers and merchants.

4.1 Consumers

The principal reason to use CBDC would likely be its safety and security in a convenient form that could be integrated into innovative private sector products and services. As central bank money, CBDC would be the safest form of money available. The other features that a CBDC might offer include a lower cost to consumers and merchants, offline payments (useful during outages and in remote locations without connectivity), a higher level of privacy in comparison to commercial options, and a design with multiple accessibility features (Table 1).

In an increasingly digital economy, the assessment of user needs should be forward looking and take account of both present and future payments needs. For example, CBDC might be designed to facilitate programmability of payments and the use of micro-payments. This might in turn enable new applications and digital functions (eg programmability could support automatic routing of tax payments to tax authorities at point of sale, or electricity meters paying suppliers directly based on power usage), and business models conducive to innovation (eg micropayments might enable alternative revenue models for digital media) (Bank of England (2020)). To accommodate these evolving user needs, a diverse ecosystem of intermediaries may be required to deliver innovation, choice and competition (Group of

[3] See Koulayev, S et al (2016), Esselink, H et al (2017), Huynh, K et al (2020), Stavins, J (2017), Schuh, S and J Stavins (2010).

central banks (2021b)). A core feature of CBDC systems should be flexibility and adaptability, which could support intermediaries in evolving their services to meet future user requirements (Group of central banks (2020)).

End-user consultations and research[1]

CBDC features — Table 1

Safety of funds	In normal and crisis periods, this distinguishing feature of central bank money relative to other forms of money could make a difference for users' adoption. The physical nature of cash helps support the identified difference between central bank and private money.
Reduced costs	Consumers' utility is affected mostly by the transaction cost of the payment instrument. Although the overall cost of a CBDC system could increase with the complexity of its design, there should be little or no (explicit) cost to the CBDC end user.
Offline	A CBDC could allow users to maintain the cash-like experience they are familiar with, together with the additional benefit of participating in the digital economy. This feature might be particularly relevant in environments where internet availability is limited or unreliable.
Security	Several factors affect an end-user's overall perception of security: the reputation of (and trust in) the issuer, intermediaries, and the underlying technology; whether the involved entities are regulated; the level of fraud protection and end-user liability; and the quality of education and marketing campaigns. A CBDC might seek to adhere to a higher security standard to address these concerns.
Privacy	Protecting an individual's privacy from both commercial providers and governments has the attributes of a basic right (BIS (2021)). CBDC could be designed to offer more privacy to users because the central bank would not have incentives to monetise the data (for more see Group of central banks (2021b)).
Accessibility	Accessible design is fundamental for both specific user groups (eg people with sensory, motor, and cognitive challenges) and the general population. CBDC end-user devices could be designed to improve on accessible digital interactions.

[1] This table summarises some reflections from findings of the selected central banks of this group. Not all the jurisdictions in our group have engaged already in end-user consultations.

4.2 Merchants

On the merchant side, it would likely be necessary to quickly onboard a large merchant base in order to drive acceptance of CBDC and therefore make the CBDC useful enough from the beginning that consumers would want to participate. When considering what payment instruments to accept, the merchant is primarily concerned with the breadth of adoption by consumers and the cost of acceptance (onboarding and ongoing). Merchants are interested in new payment instruments that could broaden their customer base because it is used by an extensive pool of consumers or reduces their costs of transacting relative to payment methods currently accepted.

4.3 Additional incentives for CBDC adoption

Differences between jurisdictions could affect strategies for adoption based on different consumer needs. Where the market lacked a material gap that CBDC could fill, both the public policy case for CBDC and the incentives for users to adopt it would likely be weaker. Under such conditions, if launching a CBDC were nonetheless judged desirable on public policy grounds, it would be particularly important to avoid frictions in its design. Conversely, in jurisdictions where there were evident gaps in the market for digital payments, there may be stronger forces favouring the adoption of CBDC as it could provide a service that is needed and exploit existing network effects.

While lessons learned from previous payment implementations may provide certain insights for potential CBDC adoption, some jurisdictions might also consider additional elements for a potential adoption strategy.

Consumers who receive payments in CBDC may be more likely to use CBDC. Public authorities might therefore be able to incentivise consumer use of CBDC by disbursing social benefits and transfers to individuals in CBDC and allowing employees to receive their salaries in CBDC. Allowing consumers to pay their taxes in CBDC may also provide a stable, concrete example for consumers to use CBDC.

Alternatively, in certain jurisdictions, legislators may consider requiring some minimum level of acceptance, eg some governments authorities such as tax authorities, some healthcare providers and pharmacies might be required to accept CBDC. This would ensure that consumers in these jurisdictions could use CBDC to satisfy some basic, but important needs. Other jurisdictions may consider such an imposition overreaching and would choose not to force private businesses to accept CBDC.

5. Designing a CBDC

- A CBDC adoption strategy in a fast-changing payments landscape would require balancing the needs of the majority of consumers and reaching smaller parts of the population.
- Different users and needs, both current and future, would need to be defined and considered in the system's design. The analysis of specific market segments through user personas and stories could provide an important method of investigating user needs and designing informative consultations with prospective end-users.

To meet its intended public policy objectives, a CBDC would need to be adopted and used at sufficient scale. The CBDC system would require some capital investment, including the costs of the central bank to set up the core system as well as some costs borne by the private sector to interoperate and provide services on top of the core system (Group of central banks (2021b)). These investments would likely be predicated on a level of adoption sufficient to achieve a scale that allows network effects. A CBDC ecosystem that was ubiquitous would also allow it to operate more efficiently and to be offered at a low cost to its users. To incentivise adoption of CBDC as a means of payment, policy levers that were carefully designed for that purpose could be used. Central banks have a variety of options for levers and safeguards as well as different system designs (Group of central banks (2021a and 2021b)).

Designing a CBDC would require a detailed understanding of the future needs of, and alternative payment options available to, users in various segments of the population. These start with, but are not limited to, the mainstream consumer who may be able to choose among a wide array of current, privately and publicly provided payment methods and future innovations.

For the mainstream consumer, a CBDC combining the safety, security, privacy and low cost of cash with the ability to be used online, may still be attractive at least for some range of purposes. In addition, it would be important to carefully explore the needs of other specific user segments, in line with the commitment of this group of central banks to provide universal access to a safe and low cost means of payments. The decision to launch a CBDC and its design would thus need to consider both the needs of the majority of consumers and smaller parts of the population. Developing this knowledge may be achieved via surveys and more precise design work with target customers.

As specific user needs evolve a CBDC would need to adapt to meet them. A flexible and extensible core CBDC system would enable innovators to identify and offer new services that meet those future needs.

Market segmentation, user personas and stories could be useful constructs to investigate user needs and design informative end-user consultations. They present a unique set of opportunities and challenges for a CBDC relative to competing payment alternatives.

The *market segments* that could be potentially relevant for CBDC are, for example, domestic retail payments, cross-border payments, and fiscal transfers. These market segments might encompass a large variety of payment use cases (eg paying a friend to split a restaurant bill, a small merchant paying staff wages, a welfare payment by the government, an international remittance). Segmentation identifies the set of variables that best differentiate end-users in terms of their needs and potential to adopt and use a CBDC.

A *persona* represents a larger customer segment. The frictions, needs, considerations and priorities of one segment could markedly differ to those of other segments.

A *user story* is a short narrative of a particular user (Table 2). It captures the user's experience, the tasks they need to accomplish, the pain points they encounter and what motivates their choices and preferences under the scenario that is described. The story raises questions that need to be addressed by the CBDC ecosystem and highlights how an end-user expects to interact with a CBDC and supporting services. A user story considers the steps that occur before a payment interaction (eg learning about CBDC, accessing and configuring a CBDC device, adding funds), steps required to complete the payment (eg identifying a payer or payee, specifying payment information), and post-payment activities (eg viewing transaction history, processing a refund, troubleshooting and cancelling a device). Each step in the sequence raises questions and brings forward requirements that highlight a variety of implementation challenges (eg technical feasibility, costs, viability of an inferred business model).

Example of user stories — Table 2

	Persona and pain point	CBDC motivation/need	CBDC design concept to gain the adoption by this type of user
A well-connected consumer	Consumer with bank account and several options for digital payments	Highly interoperable CBDC	Enhanced interoperability and privacy features, offline functionality, new features (eg programmable payments)
User with no/limited internet	Consumer on limited budget who lives in a remote region without reliable internet	Low-cost/free payment method with offline capacity	CBDC universal access device with both online and offline functionality
Unbanked person	Consumer who does not have/desire a bank account	A CBDC to make digital payments without having a bank account	Low-cost, dedicated, universal access device with a variety of easily accessible end-point solutions / a CBDC supported by institutions other than banks
User with accessibility needs	Consumer who is partially sighted	Accessible mean of payment	Single-purpose payment device with large fonts and haptic feedback
User that prioritises privacy	Consumer who does not want commercial banks to know his or her identity or track his or her spending	A CBDC universal access device	Unregistered wallet at a money service business (with limits for compliance)
The small merchant at the PoS	Retailer who wants to accept CBDC payments in store	A way of accepting non-cash payments that is cheaper and more flexible than current solutions	A CBDC designed with low onboarding cost and that does not depend on existing (costly) point-of-sale hardware

Further consultation with end-users is required to identify the payment needs and motives of consumers so that a CBDC could be designed to best match the demands of a wide set of users.

6. Concluding thoughts and next steps

As economies become increasingly digital, user needs are rapidly evolving, and innovation is reshaping user services. These developments have accelerated since the onset of the Covid-19 pandemic. To meet their intended public policy objectives, CBDCs would need to be adopted and used at sufficient scale in this fast-changing payments landscape. The weight of the different factors at play in determining whether users would adopt and use CBDCs would largely depend on the public policy objectives and future market conditions in each jurisdiction.

Experience with the introduction of previous payment innovations suggests that there is no "one-size-fits all" approach for ensuring adoption. Nevertheless, these experiences suggest some key lessons that are likely to be applicable in the future, such as satisfying user needs, harnessing network effects and not requiring new devices. Central banks should consider how the payments landscape is evolving, focusing on future innovation and demand to identify future user needs. They could accommodate evolving user needs by designing a flexible core system, and integrating a diverse ecosystem of intermediaries delivering choice, competition and innovation.

A roll-out strategy for a CBDC would require balancing the needs of the majority of consumers and reaching smaller parts of the population that could be less well served. Understanding how the future landscape is evolving would require extensive and in-depth consultations with end-user groups, identifying payment needs and monitoring innovations in payments as they arise. Designing a CBDC that optimises adoption across groups through meeting a diversity of user needs would likely require a diversity of private intermediaries in CBDC ecosystems (Group of central banks (2021b)).

The next steps for this work are to continue research on and the impact of user requirements and financial stability safeguards on system design, and the range of approaches to public engagement and consultation on CBDC.

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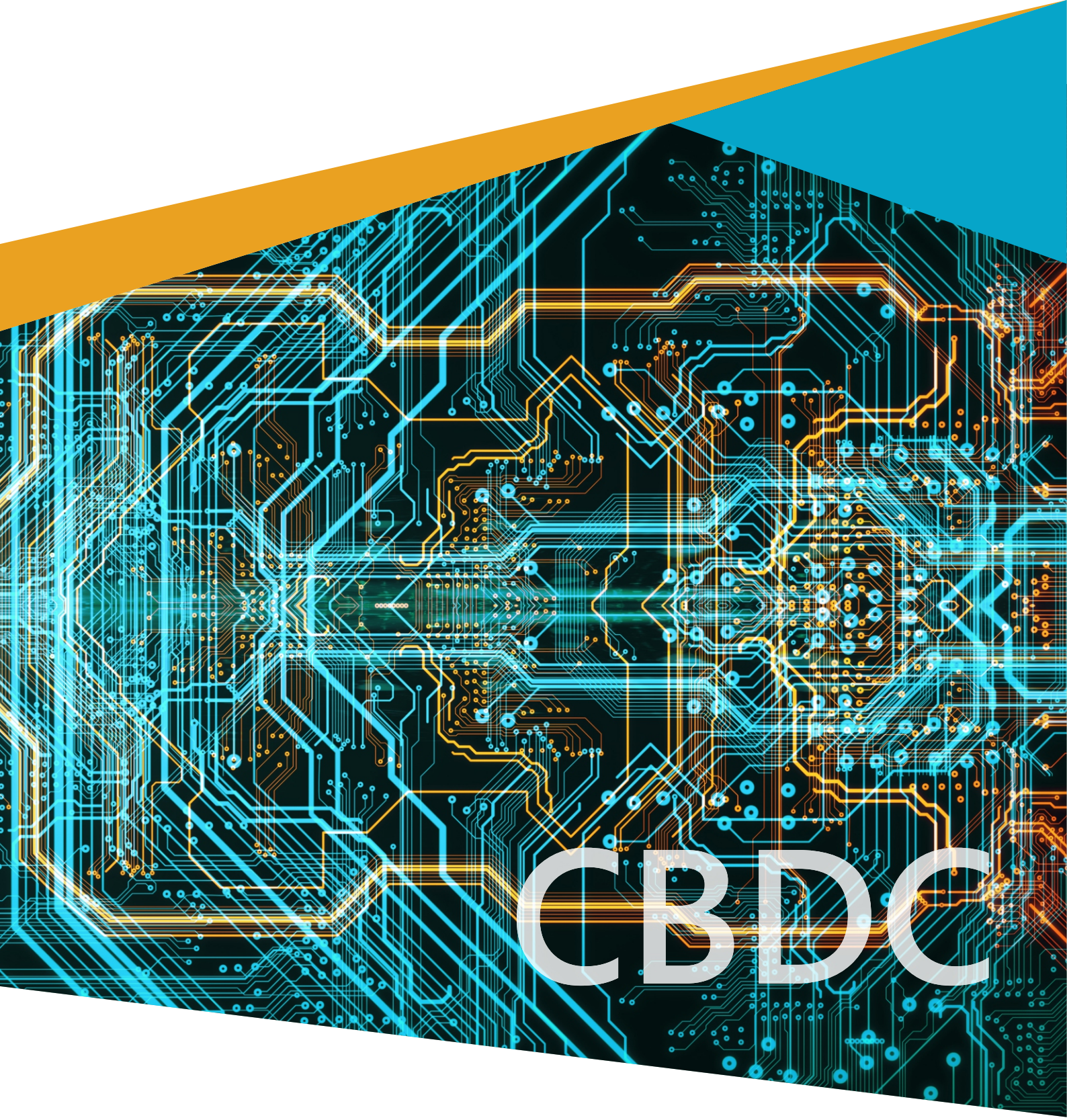

Central bank digital currencies: financial stability implications

September 2021

Report no 4
in a series of
collaborations from a
group of central banks

Bank of Canada
European Central Bank
Bank of Japan
Sveriges Riksbank
Swiss National Bank
Bank of England
Board of Governors Federal Reserve System
Bank for International Settlements

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Contents

1. Introduction and general overview

In October 2020, this group set out three common foundational principles for considering issuing a central bank digital currency (CBDC) that flow from their common objectives (Group of central banks (2020)). The first of these principles was "do no harm" – this does not mean "have no impact", but rather that new forms of money supplied by the central bank should continue supporting the fulfilment of public policy objectives and should not impede and ideally enhance, a central bank's ability to carry out its mandate for monetary and financial stability. This principle arose from a recognition that while a CBDC has the potential to provide benefits to the operation and resilience of the financial system (particularly regarding payment services), a CBDC could also affect existing financial market structures and business models, which may pose risks to financial stability as the financial system evolves, particularly via the potential disintermediation of banks.

Many jurisdictions are still in the early stages of investigating the case for introducing a CBDC, with key design choices and implementation models still under consideration. For the purposes of this work, we focus on forms of CBDC that are intended primarily for retail use, and that would co-exist with private payment systems. We make an implicit assumption that CBDCs would most likely be offered with tools to minimise criminal usage and money laundering risks ie less anonymous than cash, operating via intermediaries.[1] Many jurisdictions are also actively considering how any CBDC framework might also incorporate safeguards that could reduce uncertainty during any transition, and could also be considered on a permanent basis, eg to have CBDC function primarily as a means of payment rather than as a store of value.

The intention of this report is to consider how, and under what conditions, material risks to financial stability and the ability of authorities to maintain financial stability could arise. The report focuses on the impact on the intermediation capacity and resilience of the banking system, where risks are considered primarily relative to current bank business models and balance sheets. Implications for some aspects of market financing are also discussed. As a result, this initial assessment is bounded by three significant uncertainties: (i) the future structure of the financial system; (ii) the design of a CBDC and its underlying system; and (iii) the size and scale of user adoption.

While this report focuses primarily on potential risks and mitigants, decision-makers will, in practice, need to consider these risks against potential benefits and counterfactuals. For example, similar effects and risks could arise, potentially in a less controllable way, with certain new forms of private sector money. If issued, a CBDC would likely co-exist with private forms of money in a future financial system that could look very different from that which we observe today. Stablecoins are only just starting to be developed and will need to satisfy regulators that they are safe, but subject to that, data-driven business models and strong network effects could mean there is significant use in the future (G7 (2019)).[2] Unlike central banks, issuers of stablecoins are not bound by principles to design products that would co-exist and interoperate with other forms of money or to promote ongoing innovation and efficiency (ie the second and third principles outlined in Group of central banks (2020)). This could cause fragmentation in a payments ecosystem, just like any other closed-loop payment system (CPMI (2018)). Significant stablecoin adoption and the potential consequent fragmentation could result in excessive market power and the type of deposit disintermediation described as a risk for CBDC issuance, but with lower public benefits. As a result, the central banks contributing to this report have already identified that a CBDC could

[1] This includes the possibility that a CBDC could be fully anonymous for small value payments but not for large payments.

[2] Stablecoins vary greatly in risk profile depending on their structure and backing. Hereafter, this report uses the term "stablecoin" to refer to stablecoins that are fully backed by low-risk assets and are well-regulated, so may be perceived as a money substitute.

be an important instrument for ensuring that they can continue delivering their public policy objectives even as the financial system evolves

The report briefly outlines the factors that could affect the take-up of CBDC (also explored in Group of Central Banks (2021b)). Given the considerable uncertainty regarding CBDC demand, a range of take-up scenarios are explored. The report then explores the implications for commercial banks in benign conditions, for non-bank funding, and for the speed and scale of possible bank runs from uninsured deposits. The latter part of the report then analyses options for safeguards and mitigants, although it does not discuss in detail the possible intervention of central banks to use policy tools to offset any transitory impacts on lending.

This report cannot be conclusive and is not a statement of policy. Instead, it adds to previous analysis on this topic by pooling the expertise of central banks who are all actively engaged in similar analysis at a domestic level. By exploring these important dynamics, this report provides a framework for further work as the current financial system evolves and CBDC design options are explored and refined.

Key messages:

- To help maintain safety and stability, a CBDC would need careful design and implementation, allowing time for the existing financial system to adjust and flexibility to use safeguards.
- CBDCs would have implications for financial intermediation and would need careful design and implementation; but our analysis suggests the impacts on bank disintermediation and lending could be manageable for the banking sector. A significant shift from bank deposits into CBDCs (or even into certain new forms of privately issued digital money) could have implications for lending and intermediation by the banking sector. However, our analysis also suggests that these impacts would likely be limited for many plausible levels of CBDC take-up, if the system had the time and flexibility to adjust. This initial assessment is subject to uncertainties over the future structure of the financial system, the design of a CBDC and its underlying system, the size and scale of user adoption of CBDC and differences between jurisdictions.
- We note that the financial system is dynamic and evolving and has successfully navigated episodes of structural change over many years. Additionally, private sector developments may generate similar deposit substitution risks, irrespective of CBDC and the introduction of CBDC may generate additional innovative opportunities for banks and other financial intermediaries. Central banks would have to carefully consider how they would manage these impacts, particularly through any transition phase for CBDC.
- However additional risks to financial stability might arise if changes in the structure of the financial system due to the adoption of a CBDC were to be abrupt. Impacts would also depend on the extent of the offsetting increase in lending to the real economy by non-bank financial intermediaries. CBDC and certain new forms of digital money could also increase the latent risk of systemic bank runs. This risk is reduced in the existing system through effective banking regulation, deposit insurance, and resolution frameworks
- Central banks are exploring safeguards that could be built into any CBDC to address financial stability risks; although such measures may need careful consideration before they were used. Central banks might consider measures to influence or control CBDC adoption or use. This could include measures such as access criteria for permitted users, limits on individuals' CBDC holdings or transactions, and particular choices around CBDC remuneration. Such measures could be valuable in managing risks in any transition were a CBDC to be introduced and could potentially have a role on a longer-term basis in some jurisdictions. However, such measures would also bring challenges. The design of any measures would likely need to balance moderating the risks from high and/or rapid take up of CBDC with other policy objectives associated with a meaningful level of usage. In some cases, there could be legal and public policy issues to consider. For

example, there might be some measures that may face obstacles to public understanding and acceptance.

- Further work is needed to fully understand the entire range of effects and quantify the possible implications for financial stability from CBDCs, particularly to understand potential take-up for different CBDC designs, the optimal design of any safeguards, how non-banks and third-party providers might be affected, and the opportunities to enhance financial stability as the payments landscape continues to evolve. Observations from early CBDC launches and pilot schemes could be very useful in this regard.

2. CBDC take-up potential and bank deposit substitution

Money and payments are changing fast. The Covid-19 pandemic has accelerated a number of recent digital payment trends across advanced economies. Growth in e-commerce has expanded online payments and in-person transactions increasingly use contactless debit and credit cards. Before the pandemic, although cash circulation was growing, its use for payments had been declining in most countries and the number of ATMs falling (Boar and Szemere (2020)). At the end of 2019, cash holdings per capita ranged from around $500 to $7,000 across the jurisdictions covered by this group of central banks, while bank deposits per capita varied from $20,000 -$100,000 (Graph 1) – without a strong correlation apparent between the relative levels of the two variables across these jurisdictions. Pandemic lockdowns have apparently amplified earlier trends, by driving a decline in withdrawals and fewer opportunities to use cash, resulting in access concerns in some jurisdictions (Auer et al (2020)). In this context, more central banks than ever are investigating general purpose CBDCs (Boar and Wehrli (2020)).

Potential demand for a CBDC is highly uncertain. It would be affected by its design and implementation framework (Group of central banks (2021a and 2021b)). For example, demand would likely depend on the importance to individual users of the following factors relative to available alternatives at the time such as cash, bank deposits, e-money and other tokens:[3]

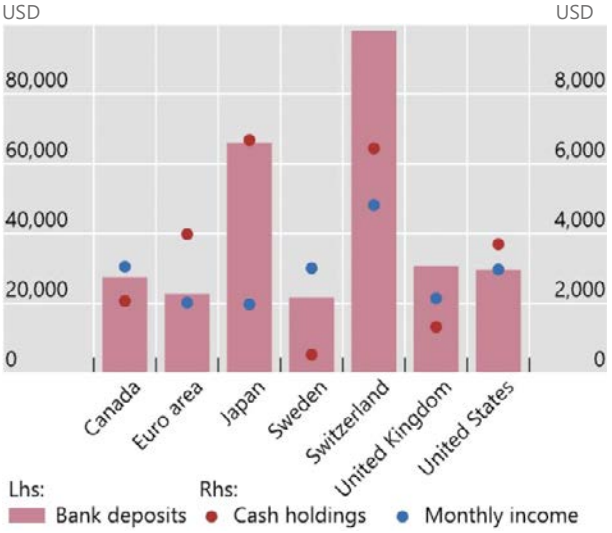
- Perceived safety versus insured or uninsured alternatives;
- Ease of access/financial inclusion;
- Interoperability with and speed of alternative means of payment;
- Technological innovation, eg programmability;
- Remuneration;
- Cost of use;
- Privacy and anonymity; and
- Ease of switching between CBDC and alternatives.

In the jurisdictions represented by this group of central banks, no decision regarding whether or not to issue a CBDC has been made and discussions are still underway regarding design choices (Group of central banks (2021a)). If jurisdictions decide to issue a CBDC, in most cases the actual introduction of CBDC could be some years away. In the interim providers of private money and tokens are expected to continuing developing and expanding their service offerings.

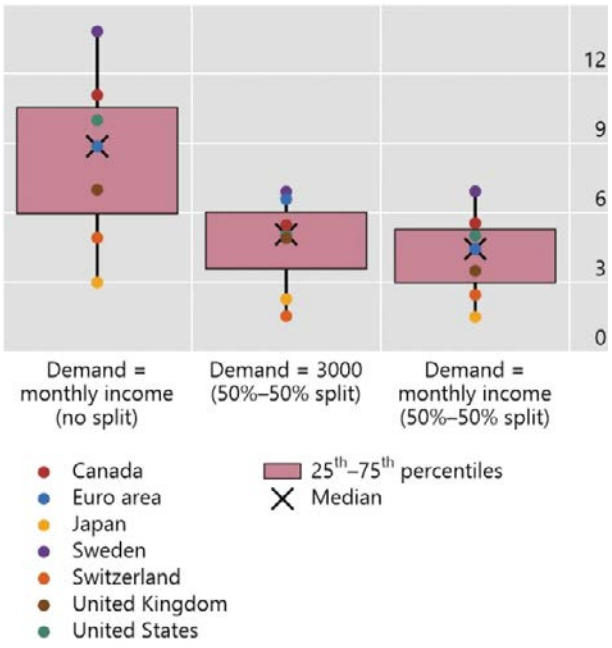
[3] Khiaonarong and Humphrey (2019) also find that demand will depend on the extent to which cash has already been substituted with other means of payment, such as bank debit cards, as without further incentives CBDC would not provide extra convenience over a bank debit card. However, in jurisdiction in which cash use is very high, demand for CBDC should be stronger due to a lack of cash substitutes already in place.

Household sector balance sheets and incomes could be one influence on CBDC adoption Graph 1

Bank deposits, disposable income and cash holdings per capita[1]



Illustrative scenarios for potential household CBDC adoption and deposit substitution[2] Percentage of bank deposits



[1] Bank deposits and cash holdings represent respectively deposit assets per capita and currency holdings of households and non-profit institutions serving households (NPISH) using 2018 OECD financial balance sheets data. Monthly income represents median disposable income of total population based on 2018 OECD Income distribution database. For the conversions of median disposable income from local currencies to USD, the USD exchange rate of 31 December 2020 is used. Per capita calculations use United Nations' World population prospects 2019 data and are based on total population. [2] "Demand" illustrations indication of CBDC take up relative to bank funding for heavily implied and stylised scenarios using 2019 data where demand is equivalent to: (i) monthly income, all substituted from bank deposits; (ii) demand per households USD 3,000 with substitution split equally between cash and deposits; and (iii) demand is equivalent to monthly income with substitution split equally between cash and deposits.

Sources: OECD financial balance sheets, non-consolidated - SNA2008, OECD income distribution database, OECD GDP database. UN World population prospects 2019. Data for euro area from ECB Statistics bulletin.

There could be material demand for an unremunerated or uncompetitively remunerated CBDC, if its other features such as cost, safety, ease of access etc are deemed to be valuable by users. If a CBDC were intended as a means of payment, rather than a form of investment, then it could pay an uncompetitive interest rate, negative interest (for example, to avoid undercutting bank deposits in jurisdictions where interest rates are negative) or be left unremunerated. Demand for existing non-interest-bearing electronic money such as "e-money" in the UK and EU has been relatively low. However, CBDCs would be as safe as cash, with added electronic benefits and possibly attracting greater demand.

A remunerated CBDC would be an even more attractive substitute for cash, low interest-bearing deposits or other cash-substitutes. According to Li (2021), remuneration is one of the most important attributes that affects the potential demand for CBDC. The magnitude of the demand would still though depend on a range of factors, including safeguards (discussed in Section 5), and convenience factors such as the ease of use via digital wallets. It could be attractive to households that are particularly risk-averse or have already spread deposits across multiple bank accounts to minimise balances above deposit protection limits. Businesses might also wish to transfer some of their uninsured balances to a CBDC.

That said, demand inertia might limit or slow sizable shifts to any CBDC, unless it were very competitively remunerated and/or offering better functionality. Some studies have shown that demand

for deposits is relatively insensitive to interest rate differentials between banks, due to demand inertia.[4] But CBDCs would be a new asset and the cost to users of setting up a new relationship could be very small.[5] Therefore, the elasticity of demand for CBDC might be somewhat greater if perceived barriers to transferring money to it are lower.

Studies to date that attempt to estimate CBDC take-up find very wide ranges, reflecting the large uncertainty around CBDC adoption, and find high sensitivity to CBDC features. Li (2021) uses Canadian household survey data to quantify the expected demand of CBDC by households and estimates that households could hold from 4% to 55% of their combined cash and deposit holdings in CBDC depending on the features of the CBDC. In particular, the lower estimates would apply if the CBDC had more cash-like features, while the higher estimates would likely reflect a CBDC designed with characteristics that made it competitive with bank deposits. Bank of England (2021) considers an illustrative scenario in which about 20% of household and corporate deposits migrate to CBDC owing largely to non-financial factors such as safety and convenience. A simple exercise replicating the analysis of Bindseil (2020) for G20 economies where data is available, which assumes that CBDC take-up is driven by monthly incomes of people over 14 years old, and three macroeconomic metrics (income distribution, population size, and banks' share of funding from households), suggests that the domestic demand for CBDC could range between 4% and 12% of bank funding, although these figures would be lower if part of the demand reflected substitution from cash (Graph 1).

In time, data from early CBDCs should provide insight on their take-up. Until then, analysis of CBDCs' implications should consider a range of potential take up scenarios given the significant uncertainties. In the coming year, data should start to become available on the rollout of some early CBDCs, notably the Bahamian "sand dollar" launched in October 2020 and the digital Yuan currently in pilot testing. In particular, the sand dollar also has a notable two-tier system that should provide insight on the importance of some non-pecuniary factors. There are two tiers of sand dollar account, both of which are unremunerated, but "Tier 1" accounts have lighter identification requirements, cannot be linked to bank accounts and so have lower holding limits and lower monthly transaction limits than Tier 2 accounts.[6] Authorities could also consider launching consumer attitude or other market research surveys to follow public awareness of CBDCs, their features and interest in take up across the population.

[4] For example, Chiu and Hill (2015) estimates that a 1% increase in the bank deposit rate was associated with an increase in the stock of deposits of around 0.3% over 12 months.

[5] In principle, users could hold a CBDC without a bank account (through a digital wallet). Hence the cost of setting up a new would likely be lower and the elasticity of demand higher.

[6] https://www.sanddollar.bs/individual

3. Implications for bank funding, lending and resilience

The potential for the introduction of a CBDC to affect financial stability risks arises primarily from a significant substitution away from private money, while central bank cash-to-CBDC substitution is generally regarded as having no implication for financial stability[7]. Even as the financial system is evolving rapidly, private banks are in all jurisdictions still the dominant source of private money. The money creation process is intrinsically intertwined with bank credit provision, which in turn supports a banking system providing a wide range of intermediation and payment services. As a result, the analysis that follows focuses on the implications of CBDC substitution for bank deposits (and later other money instruments).

Absent limits to individual holdings, a CBDC (like other forms of digital money) could lead to higher volatility in deposits and/or a significant, long-term reduction in customer deposits. This could, under certain circumstances, affect bank profitability, lending and the overall provision of financial services. Customer deposit funding is at the heart of the commercial banking business of maturity transformation and intermediation services. Away from issues of the zero-lower bound, any material loss in customer deposit funding would require banks to consider combinations of actions to try and maintain regulatory ratios and risk-adjusted profitability, eg:

- Switching to alternative market-based funding sources which could be more expensive and, in some cases, less stable;[8]
- Reduction in assets/deleveraging;
- Increased risk taking to mitigate near-term margin compression;
- Increased lending rates;
- Actions to offset any lost fees and commissions on activities associated with customer deposits, eg ancillary payment services. These could include actions that improve competition for customer deposits or leverage a role as CBDC intermediary.
- Cost efficiencies (eg lower cost of cash handling).

There is a small but growing set of literature seeking to consider the magnitude of these challenges, and their implications on bank lending (availability, cost and economic impact; Box 1). While there are studies suggesting both positive and negative overall effects of a CBDC on aggregate lending and economic activity, a common theme is that maintaining bank profitability levels could be challenging, and that the magnitude of the implications will depend on the exact design of the CBDC. Assumptions regarding the substitutability between deposits and CBDC, the level of competition in the banking sector, the functioning of the market for loans from non-banks, and the new role of the central bank are crucial determinants of the structural implications of CBDC.

A stylised model of an aggregate banking system can shed light on how material some of these challenges may be in typical, benign conditions, for a range of hypothetical CBDC take-up scenarios (assuming an environment with positive interest rates). Taking some high-level features of an aggregated banking system balance-sheet, combined with some simplified assumptions on how that system may respond to a loss of customer deposit funding, can provide a guide to the scale of knock-on effects for funding costs, effective lending rates and bank profitability (see Annex A for details of the model).

Specifically, we can consider one case where the banking system seeks to offset all CBDC capture of customer deposits via long-term wholesale funding – a costlier alternative to customer deposits. In this case, following deposit outflows, banks seek to maintain their lending volumes and leave their regulatory

[7] Substitution away from cash towards CBDC may ultimately affect the economic value of continuing to issue cash, although most jurisdictions have committed to ongoing cash production for the foreseeable future.

[8] In the short term, banks may also be able to turn to central bank funding, subject to central banks' willingness to lend.

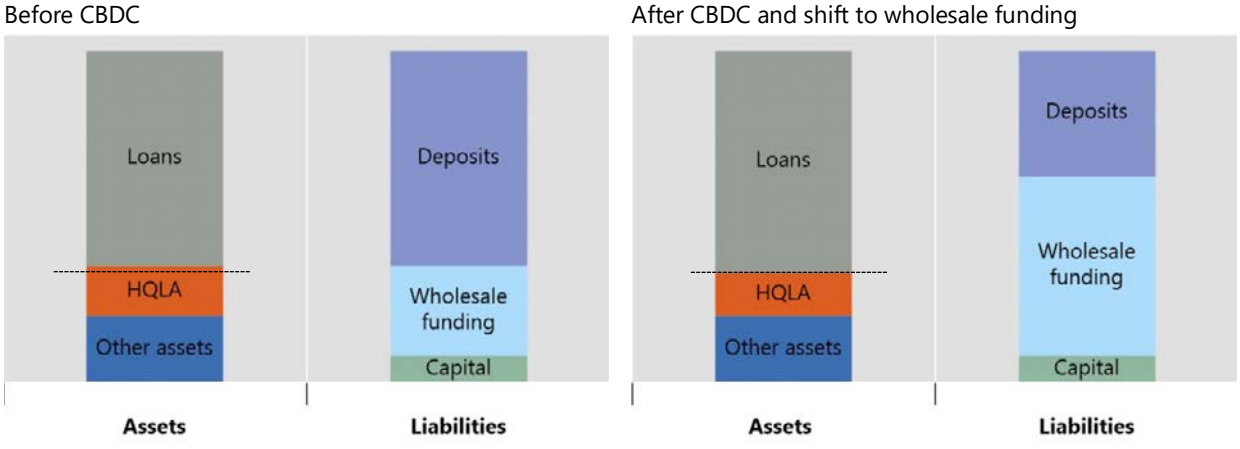
liquidity ratios unchanged.[9] They do this by issuing long-term wholesale debt to buy enough high-quality liquid assets (HQLA). Under current regulatory design, banks do not need to replace all their lost deposits with wholesale funding because long-term wholesale funding requires less HQLA to be held against it than deposits (Graph 2). For simplicity, long-term wholesale funding rates, non-interest income and non-funding expenses are assumed to remain unchanged. Banks' weighted average funding costs increase due to the substitution of deposits with relatively more expensive wholesale funding. Therefore, for a range of CBDC take-up scenarios, we estimate how much this response increases banks' weighted average funding costs and reduces net interest margins (NIMs) and return on equity (RoE), other things held constant. Finally, banks may seek to offset that impact on their profitability by raising lending rates, which for simplicity is assumed not to trigger reduction in lending volumes.[10] We estimate by how much banks would need to increase lending rates to maintain profitability.

The model itself does not depend on the level of the central bank policy rate because results are a function of the degree of deposit outflow and the spread between wholesale funding and deposit rates.

The introduction of a CBDC could weigh on banks' profitability if banks kept lending (at unchanged interest rates), for a wide range of take-up scenarios (Graph 3, left-hand panel). The model estimates that wider spreads between deposit and wholesale funding rates, coupled with sizeable deposits outflows, translate into a larger profitability loss.[11] If banks were to maintain their profitability, they may seek to increase the interest rates on loans (Graph 3, right-hand panel). Both graphs are shown under different illustrative spreads between wholesale funding and deposit rates (0.5 to 2% pts). As an illustrative guide, a line showing the average wholesale funding-deposit spread for advanced countries from 2017 to 2021 of 0.63% pts is included in the graphs.[12] The stressed outflow factor in the liquidity coverage ratio (LCR) and the initial LCR are assumed to be 15% and 125% respectively, representing a range including retail deposits and business operational deposits.

Illustration of aggregate banking system balance sheet before and after CBDC introduction, assuming replacement with long-term wholesale funding

Graph 2



Source: Working group

[9] Focusing on the liquidity coverage ratio (LCR).

[10] This is a partial equilibrium exercise, ie banks can adjust their rates without changing quantities.

[11] To give a sense of the magnitude of RoE measured as a simple average across the euro area, "other Europe", the United States and "other advanced and emerging markets", the RoE was 7.5% and 8.9% (on average) in 2016 and 2000-2016, respectively. Data source: CGFS dataset.

[12] This spread is indicative of relatively benign conditions and is in part a function of the low interest rate environment and strengthened bank resilience since the global financial crisis. The spread widened during the global financial crisis (ie stress conditions) to a high of around 3% pts.

Box 1

CBDC impact on lending and economic activity - insights from research

Although still relatively small, the emerging literature on the potential impact of CBDCs on banking systems already offers a wide range of argumentation with some areas of consensus. This box draws together the high-level findings from a range of studies that focus on how a CBDC affects issues relevant to financial stability, primarily through impacts on bank deposit funding, competition, risk-taking/market discipline and susceptibility to bank runs.

Researchers are not unanimous on the potential impact of a CBDC on bank deposit funding but many note impacts on competition. A sizeable body of literature (CPMI-MC (2018), Fernandez-Villaverde et al (2020), Keister and Sanches (2019)) stipulates that a CBDC would structurally decrease deposit funding available to commercial banks as a CBDC, being on a par with deposits with regard to liquidity and convenience, would also offer advantages as a safe haven asset. That said, Chiu et al (2019) and Kumhof and Noone (2018) argue that in an imperfectly competitive deposit market, the existence of CBDC as an outside option forces banks to match the CBDC rate to retain their deposits, which would eventually have a crowd-in effect of encouraging saving. Andolfatto (2018) argues that the introduction of interest-bearing CBDC will increase financial inclusion in systems in which the banking sector is not perfectly competitive while simultaneously diminishing demand for cash.

Many studies argue that CBDC is likely to weigh on bank profitability and lending. If banks respond to a CBDC by increasing reliance on market funding, then depending on the type of market funding (ie wholesale deposits, long-term debt, longer-term money market instruments), banks' maturity transformation and their liquidity risk may face upward pressure because of more reliance on less stable funding sources, or some downward pressure if market discipline increases (Mancini-Griffoli et al (2018)). They say that the volatility of market-based funding may increase the pro-cyclicality of bank lending.

Competition from CBDCs may also prompt banks to increase deposit rates. In Keister and Sanches (2019), higher deposit rates lead to lower lending as some projects that are profitable at a lower cost of funding fail to secure cost-efficient bank financing. Agur et al (2019) and Mancini-Griffoli et al (2018) note that when banks have sufficient market power, they may try to compensate for higher deposit rates by increasing the interest rates charged on lending, lowering the demand for loans. Piazzesi and Schneider (2020) argue that the introduction of a CBDC by the central bank could cause a reduction in commercial bank deposits which would consequently translate into more expensive credit lines. The authors suggest a decline in welfare if the benefits of the CBDC are outweighed by higher credit line costs. The analysis is based on several strict assumptions such as that CBDC is seen only as a deposit substitute (and not as cash alternative) and that banks main function is liquidity provision.

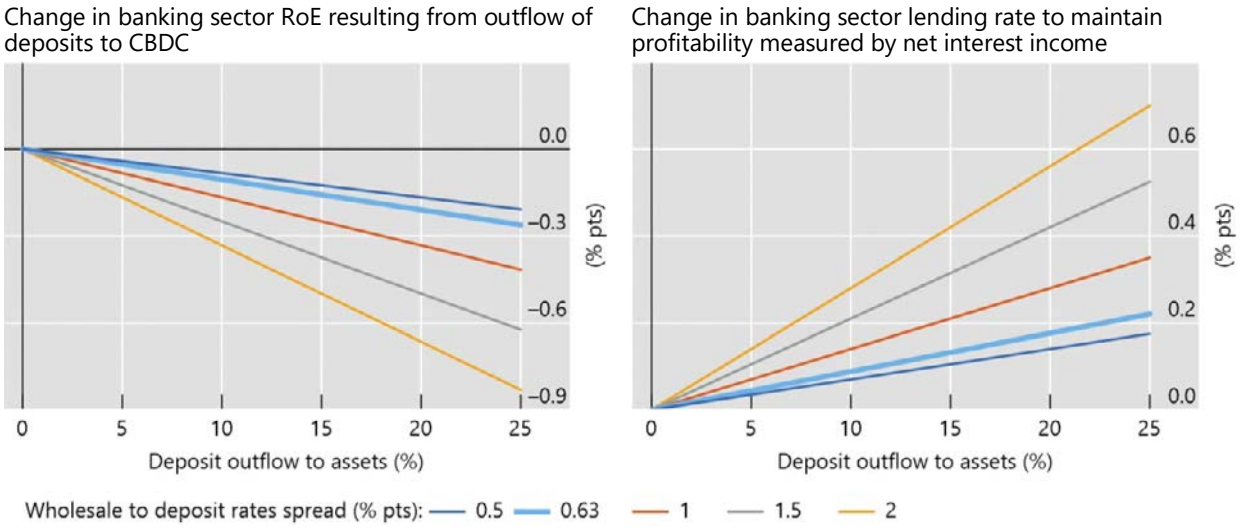
Some studies note the potential for increased competition created by a CBDC to increase the overall depositor base, in turn expanding lending and/or reducing borrowing costs. Andolfatto (2021) argues that higher deposit rates could increase the deposit base, and lower borrowing rates thus expanding banks' lending. Similarly, Chiu et al (2019) conclude that under imperfect bank competition in the deposit market, higher deposit rates can increase lending by increasing deposit demand. They argue that, even when CBDC is not used in equilibrium, its introduction provides a lower bound on deposit rates, limiting monopoly profits of banks in the deposit market and inducing them to lend more.

Another set of studies focus on the risk that a CBDC may increase depositors' sensitivity to system-wide banking crises by facilitating the transfer of deposits. The availability of CBDC might not have a large impact on individual bank runs as it is already possible to digitally and instantly transfer money between a weak and a strong bank (Kumhof and Noone (2018) and Carstens (2019)). However, during a systemic banking crisis, transfers from bank deposits into CBDC would face lower transaction costs than those associated with cash withdrawals (such as going to the ATM, waiting in line, etc.), and would provide a safe-haven destination in the form of the central bank. The lower costs of running to CBDC compared to cash imply that more depositors would quickly withdraw at a lower perceived probability of a system-wide bank solvency crisis (Broadbent (2016) and Callesen (2017)). Yet, the impact of a CBDC on the speed, scale and frequency of systemic bank runs depends crucially on its design, and on the credibility of deposit insurance (Mancini-Griffoli et al (2018)).

The scenarios just described are subject to risks in either direction. On the one hand, non-linearities and general equilibrium effects, not included in the modelling, could imply more costly outcomes. For example, the cost of wholesale market funding may increase given increased demand for it and as investors may seek increased compensation for risk if their own portfolios rotate from HQLA (likely government bonds) towards bank debt. On the other hand, any increased demand for government bonds by banks may push down government bond yields. Banks' long-term wholesale funding cost is made up of the long-term risk-free rate plus a credit spread. Any fall in long-term risk-free rates from banks buying government bonds would help mitigate any increase in banks' wholesale debt funding costs.

Illustrative exercises estimate the potential for impacts on bank profitability and lending if CBDC prompts an outflow in customer deposits[1]

Graph 3



[1] See Annex A for details on data sources and model parameters.

Source: Country Banking Data Tables from CGFS publication No. 60, BIS bank level asset data and BIS bank level deposit and CDS rates. Data is obtained for a subset of advanced economies.

At the same time, if a CBDC led to lower cash usage, banks may also be able to reduce the costs associated with cash handling, helping their overall profitability. Cash operations have been estimated to account for between 5% and 10% of total bank operating costs (McKinsey (2018)), suggesting the potential for significant cost savings from lower cash handling. Actual cost savings would likely be lower, however, as many jurisdictions have indicated that even if they introduce a CBDC, they intend to maintain physical cash for the foreseeable future; in addition, many jurisdictions have policy goals to maintain widespread access to cash and cash distribution across their country. Table 2 sets out some of the key factors that could lead to a higher or lower change in lending rates than in the modelled scenario.

Overall, this analysis suggests that a CBDC could impose some costs via different channels, such as lower bank profitability (and in turn, bank resilience), higher bank lending rates or reduced lending - although this work does not consider how these costs compare to the potential welfare benefits of a CBDC. Moreover, similar effects could emerge in case of a large take up of new forms of private money, such as stablecoins.

In any new steady state with meaningful take-up of CBDC or other digital forms of money, banks may have to react to a smaller deposit base. If banks choose to cut lending in order to repair their liquidity positions, they would destroy a deposit somewhere else in the banking system, propagating the liquidity problem to another bank. So, banks must in aggregate opt for alternative funding sources, such as

issuance of long-term debt.[13] This means that their funding costs would increase. It could also mean that loan prices may become more sensitive to market conditions. While central banks can in principle also be a source of alternative funding, such funding – whether temporary or structural - may need to be provided against lower quality collateral as only that would increase HQLA for banks. The long-term implications of any structural central bank funding as well as the monetary subsidy of funding would need to be carefully considered further. In addition, the quest for different funding sources may result in an increased reliance on non-bank sector, raising the need for regulatory supervision and possibly creating regulatory perimeter issues.

A CBDC could also pose greater challenges for some business-models or parts of the banking sector. Large banks with relatively higher share of (non-interest or low interest bearing) transactional deposits may be more likely to lose deposits to the CBDC than banks with higher-rate savings deposits (eg building societies). Conversely, those large banks may have better access to wholesale debt markets than smaller banks, enabling purchases of HQLA. Some small banks with a business model focused on payments may be particularly vulnerable to the introduction of a CBDC.

Sensitivities of lending rates to assumptions Table 2

	Upward pressure on the change in lending rates	Downward pressure on the change in lending rates
The cost of long-term wholesale debt, and banks' weighted average marginal funding cost	Cost might rise as banks increase debt issuance if investors want additional compensation to shift their portfolios from government bonds to bank debt. Bank debt is often bought by institutional investors in international markets. So the impact on lending rates could also depend on international cross-currency swap markets.	Cost might fall if banks' higher demand for government bonds (HQLA) resulted in lowering government bond yields. In that case, the risk-free rate component of wholesale funding costs could fall. However, a fall in government bond yields would also reduce the return banks earned on their HQLA portfolios and so offset the benefit on the funding side.
Deposit rates	Could increase if banks bid up deposit rates to slow non-pecuniary deposit outflows or if the interest rate on a CBDC is attractive.	
Non-interest income	Banks could seek to increase lending rates if they lose non-interest income associated with deposit activity. Alternatively, they might charge more fees or seek other business activity.	Banks could seek to reduce lending rates if they lose non-interest income associated with lending activity.
Banks' marginal funding rate used to price lending may not include deposit costs		Banks may price lending based on long-term wholesale funding costs alone. In that case, the impact on lending rates from CBDC would depend on the extent to which increased long-term wholesale issuance drove up long-term wholesale funding rates. In this case, the shift from deposit to wholesale funding may have less impact on banks' loan pricing.
Competition for lending		An increase in loan rates might be mitigated by competition from non-bank lenders and capital markets. However, this effect could be stronger for some forms of lending (eg large corporates) than for others (eg SMEs).

[13] Banks could also issue shorter-term wholesale debt to replace lost deposits but could face greater subsequent hurdles meeting regulatory liquidity requirements (eg the LCR).

At the same time, introduction of a CBDC has the potential to offer new opportunities for innovation, which may benefit banks, and non-bank/third-party providers of financial services, supporting a competitive and diverse financial system. Depending on its functionality and level of interoperability, the introduction of a CBDC could enable banks and other intermediaries to offer innovative payment services to their customers (such as programmable payments). Or it could allow for more diverse forms of finance, with less need to rely on centralised payment intermediation, eg less reliance on correspondent banks in international payments. This could facilitate new opportunities for innovation and increase the resilience of the system overall – subject to authorities ensuring appropriate regulation of all parties. In parallel, greater competition for deposits, and possibly also for lending, could also bring in new entrants or encourage expansion of lending by non-banks. Again, more diversified sources of finance would tend to increase the resilience of the financial system overall, subject to robust prudential frameworks.

It is also possible that non-banks would extend credit to replace some bank lending directly, if they chose to adjust their own portfolio composition – although this may in turn affect non-banks' provision of other financing, including to banks. Many advanced economies operate with relatively high levels of non-bank finance with correspondingly smaller shares of household assets held as deposits with the banking system. While it provides more diverse forms of finance, non-bank finance is unlikely to be a perfect substitute for bank finance, especially for lending to some smaller companies. That is because this lending often requires the lender to have specialist information. This is currently an area in which commercial banks have an advantage given the information to which they have access on their customers' deposits.

CBDC could partially replace banknotes in circulation, which would result in a swap between these two liabilities on the central bank's balance sheet. CBDC could also substitute a share of customer deposits at commercial banks, resulting – in the first instance – in a swap between CBDC and reserves on the liabilities side of the central bank's balance sheet, if banks have enough central bank reserves. The latter case would probably have a more significant impact on the aggregate balance sheets of various sectors in the economy, in particular the commercial banking sector.

In a scenario where CBDC leads to a significant decline in deposits at commercial banks and reduced the level of aggregate reserves in the system sufficiently to exert pressure on key short-term money market rates, the central bank could adjust the supply of reserves to stabilise rate pressures. It would have two main options to do so – either through asset purchases or lending operations – both of which would increase the size of the central bank balance sheet relative to the pre-CBDC case. Increasing reserves through asset purchases could not only impact those asset markets in which the central bank was making purchases, such as government securities, but also enlarge the central bank's footprint in these markets.

Once any transition to a CBDC had occurred, central banks would need to consider the size and volatility of the aggregate CBDC liabilities on the central bank balance sheet in steady-state. If the aggregate CBDC liability proved large and volatile, it could be more difficult for a central bank to forecast components of its balance sheet, with potential consequences for the size and frequency of central bank operations in money markets. Flows into and out of CBDC that are not matched by corresponding shifts in the demand for banknotes would affect the amount of reserves in the system, in the way that changes in the stock of banknotes or central bank deposits held by non-monetary institutions (eg the finance ministry, foreign central banks, or financial market infrastructures) currently do.

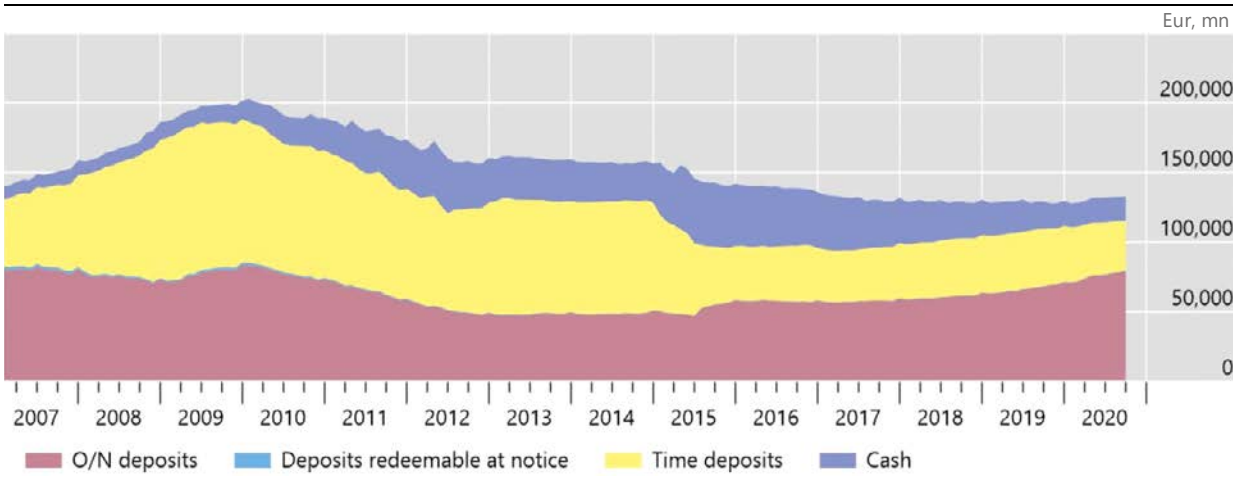
4. Possible effects on systemic bank runs or abrupt money-market withdrawals

In addition to the potential impact of CBDC in benign conditions, during crisis periods a CBDC could be perceived as a safe haven making bank deposits, particularly uninsured deposits, more flighty and thus increasing the risk of bank runs (see Box 1 for literature). Online cash transfer services, digital currencies and fast payments services have already increased the ease of withdrawing deposits in recent decades. At the same time, stronger prudential regulation of banks and reinforced deposit insurance schemes in many countries since the financial crisis have reduced incentives for retail and wholesale customers to run on banks. Nonetheless, the introduction of a CBDC (or certain new forms of private money) might increase this risk in stress by providing an easily accessible recourse to a safe asset - although the specific mechanics of any run would be impacted by the legal and operational design of the CBDC and its handling by banks or other financial service providers. For example, there may be distinct dynamics related to a CBDC that is held/serviced by financial institutions for their customers. Moreover, limits on individual holdings or withdrawals could be introduced by authorities or intermediaries to manage the risk of sudden deposit outflows (see Section 5).

Evidence from previous systemic bank runs indicate how powerful the impetus of a bank run is, and therefore how the reduced transaction costs of a CBDC could exacerbate bank runs. For example, when the Japanese financial crisis erupted in the late 1990s, it took a week or so for the deposits of failed banks to fall by 10% (Table 3). The central bank and regulatory body thus had some time to plan and provide ex-post interventions, including any changes to deposit insurance and lender of last resort, to tackle the crisis. As for the bank runs that happened amid concerns over "Grexit", the deposits of Greek banks fell in total by just over 30% and about 25% respectively from 2010-2012 and 2014-2016 (Graph 4). If funds could have been shifted into a CBDC, the damage to the Greek banking system could have been greater still.

The Greek banking system household sector deposit and cash outflows

Household sector deposit and cash profile of Greek banks — Graph 4



Note: Outstanding amount of bank deposits of households and non-profit institutions serving households (NPISH) reported by Greek monetary financial institutions. Cash represents currency holdings reported by Greek households and NPISH.

Source: ECB Monetary financial institutions balance sheet items. ESA2010 quarterly financial and non-financial sector accounts.

Beyond banks, it is possible that CBDCs could be a substitute for investments in other low risk, liquid assets, such as Money Market Funds (MMFs) and Treasury Bills, leading to abrupt shifts in their funding. There are a subset of non-bank intermediaries and capital instruments that have some asset features (and in some cases, payment features) that are close to bank customer deposits and cash. For example, at end-2019, there were an estimated $7trn of assets under management in money market funds (Avalos and Xia (2021)). Depending on its design features and relative remuneration, introduction of a CBDC could be an attractive alternative for some risk-averse holders of other cash substitutes, even in benign conditions. This in turn could reduce the demand for assets that such funds invest in, possibly affecting yields in turn. That said, in benign conditions demand to move into CBDC could be limited if many investors, including institutional or retail investors, also have some appetite for risk by nature. The extent of this demand is also likely to be contained if CBDC is restricted to retail use.

Outflows of deposits from banks during the 1990s Japanese banking crisis

In yen, billion Table 3

Bank	Day of announcement	Deposits outstanding on final business day	Outflow of deposits (accumulated)		
			First day	First week	First month
Hokkaido Takushoku Bank	17 Nov 1997	5,603	210 (4%)	856 (15%)	1,571 (28%)
Tokuyo City Bank	26 Nov 1997	576	40 (7%)	110 (19%)	173 (30%)
Kokumin Bank	11 Apr 1999	538	44 (8%)	123 (23%)	173 (32%)
Kofuku Bank	22 May 1999	1,689	59 (3%)	191 (11%)	273 (16%)
Tokyo Sowa Bank	12 Jun 1999	1,994	60 (3%)	232 (12%)	466 (23%)
Namihaya Bank	7 Aug 1999	1,457	40 (3%)	102 (7%)	196 (13%)
Niigata Chuo Bank	2 Oct 1999	918	32 (3%)	84 (9%)	152 (17%)

Source: Nakaso (2001)

Large-scale MMF outflows in the global financial crisis (GFC) and at the onset of the Covid-19 pandemic also indicate that a CBDC could increase the risks of "runs" from non-banks in stressed conditions. This risk is greatest for non-banks reliant on short-term funding. The onset of the GFC saw a very large shift out from prime MMFs in the US, which had negative effects on other short-term markets. Although the financial reforms after the crisis resulted in a reallocation of funds from prime MMFs to government MMFs, prime MMFs faced large swings in inflows and outflows in the initial months of the Covid-19 pandemic, reflecting periods of investors withdrawing balances in a "dash for cash" and also investors turning to MMFs as a safe-haven in other periods (Eren et al (2020)). The critical question is whether and how the introduction of a CBDC would affect the run dynamics in prime MMFs by offering an alternative safe haven other than reallocating funds to government MMFs. CBDC remuneration and the ability to redeem MMF shares directly into CBDC without going through the payment system are important considerations. Contrary to institutional MMFs, retail prime MMFs in the US did not experience large

outflows during the Covid-19 pandemic. As discussed above, concerns about elevated run risk in MMFs would be mitigated if CBDC were restricted to retail use.

In addition, a structural shift away from transactions in some money markets could affect the robustness of critical interest rate indices. Money market transactions specifically overnight unsecured deposit transactions, in which MMFs are key participants, are also used to determine interest rate benchmarks, such as SONIA or EONIA. As was seen in the past with LIBOR, the integrity of indices, which matter for financial market functioning, requires sufficient transaction volumes in the underlying markets.

5. Options for safeguards

The previous sections have described how a large shift from bank deposits to CBDC has the potential to affect current banking sector business models, possibly in a disruptive way, reducing the availability or increasing the cost of lending and even increasing the risk of systemic runs. Disruptions may occur in any case and be less easily controlled with the introduction of new forms of private money such as stablecoins and could also involve other parts of the financial system. But whether these challenges would indeed be disruptive would depend on the scale of the take-up of CBDC (or private digital money), how quickly any substitution occurs and extent of offset from third-party and non-bank financial service providers.

CBDC design or its framework can help control the risks to financial stability, including by mitigating risks that could arise with new forms of private money as noted in Section 1. Depending on the specific rationale in a jurisdiction for pursuing CBDC, the functionality of the CBDC or the payment infrastructure and entities that support it could be tailored to fulfil that rationale while mitigating side-effects. Any safeguards aimed at moderating take-up must also be balanced with allowing a CBDC to fulfil its policy objectives, and some safeguards may be easier to implement than others.

5.1 Measures to moderate CBDC take-up and limit substitution

Moderating CBDC take-up would be the most direct route to mitigate the identified risks from the potential substitution of CBDC for bank deposits and relatively low risk assets including money market funds. Authorities could implement two broad categories of safeguards that moderate CBDC take-up and usage: (i) quantity-based safeguards; (ii) price-based safeguards (Table 4).

CBDC design options to moderate take-up Table 4

Quantity measures/ limits	Max. holding limit	Differentiated limits	Transaction limits
Price measures/ remuneration	Unremunerated / Negative remuneration	Tiered remuneration	
In-crisis measures	Gates/switching limits	Banking support	

Quantity-based safeguards would restrict the use of CBDC through imposing hard limits on the transfers and/or holdings of CBDC. Quantity limits can either be stock-based (central banks limit the amount of CBDC held by individuals/individual account holders) or flow-based (restrictions on the amount of CBDC that can be transferred within a given time period, eg a day, by an account

holder). The magnitude of the quantity restrictions could be calibrated to reflect the typical use of cash and common household payment uses.

Price-based safeguards (via remuneration or fees) could be used to disincentivise holdings of CBDC or large payments in CBDC (without restricting them). Central banks could consider paying uncompetitive interest rates on CBDC holdings to disincentivise use.[14] The remuneration system could either be a single-tier or multi-tier. In a single-tier system, holdings of CBDC would be remunerated at a rate irrespective of the amount held. In a two-tier system, up to a predefined threshold amount (q_1), CBDC holdings would pay a certain return (r_1); the amount held in excess of q_1 would be remunerated with a lower return ($r_2 < r_1$). Central banks would need to make decisions about how to apply interest rates (for example, whether on a spot amount or on a period average basis), taking account of the technical possibilities. In addition, central banks could consider charging a fee (either fixed or progressive) on transfers of CBDC that exceed a certain amount.

A combination of quantity- and price-based safeguards can also be considered. For example, a central bank could consider a two-tier remuneration system with limits on the amount of CBDC that can be transferred in a given day. Whether implemented in parallel or not, the existence of the above design features would reduce the attractiveness of a CBDC as a store of value and thus reduce the extent of disintermediation and the possible ensuing financial stability risks.

Limits could also be applied varyingly for different CBDC account holders to differentiate between businesses and households. Depending on the motivation for launching a CBDC and its framework, central banks could consider different limits or frameworks in place for households than for businesses. For example, tighter limits on business usage may moderate overall CBDC take-up while still protecting goals for widening financial inclusion.

Such limits could be imposed on a permanent basis or on a transitional basis. Some central banks may see a case for structurally limiting the extent of CBDC take-up, and risks from substitution with private money. Others may prefer to use measures only during a transitory phase to slow initial take-up and allow time for the financial system to adjust.

Calibration of any safeguards would likely need to balance moderating the risks from high and/or rapid take up of CBDC with other policy objectives for a meaningful level of usage. The illustrative analysis in Section 2 of this Report indicates that central banks could form a reasonable understanding of what level of CBDC take-up could lead to a level of bank disintermediation that they deem too high - that level may vary by jurisdiction and its financial structure. However, central banks would also likely wish to still ensure some meaningful holdings of CBDC, to meet goals such as providing the public with access to a safe means of payment in central bank money, enhancing inclusion and accessibility, or encouraging auxiliary services to be developed around the CBDC that form part of its economic benefit. Calibration of any safeguards might therefore need to avoid being too restrictive or too uniform.

Some safeguards could face implementation issues that need to be addressed. Implementation of safeguards requires access to relevant data (even if automated) and additional processing. For example, considering quantity limits on holdings, settlement of CBDC transactions

[14] In theory, the interest rate on CBDC could be negative. However, the existence of cash (which has zero remuneration) would limit this possibility

could be guaranteed only by introducing a waterfall mechanism[15] – this would require monitoring and retaining information on both holdings and transactions. Safeguards targeting CBDC transfers (such as fees or limits on the transferable amount) may not require access to as much information, as they could be applied on the transaction alone. Tiered remuneration systems may need not only implementation of the remuneration schedule itself, but also implementation of tools to prevent arbitrage (ie to prevent the emergence of a secondary market for CBDC where holders of CBDC in excess of q_1 would ask other users to hold their CBDC to avoid the lower remuneration $r_2<r_1$ (any return between r_1 and r_2 would make the transaction profitable for both parties)); such arbitrage would however be limited by operational hurdles.

In some cases, there could be legal and public policy issues to consider with respect to the premise of imposing limits and/or negative interest rates on household wealth held by the public. If the introduction of the CBDC is deemed worthwhile and its design is reasonably fit for its intended purpose, limitations on holdings may require changes to existing legal frameworks or be at odds with the general public's expectations (although limits to cash payments for security and fraud reasons do exist in some jurisdictions, such as the EU). Similarly, direct application of negative interest rates to household wealth, as opposed to indirect application passed through the banking sector, may be felt more keenly by the population. Moreover, in jurisdictions where the central bank is not otherwise contemplating negative interest rates, this tool may be impractical. Lastly, to the extent that CBDC introduced with one set of attributes leads to substitution behaviour and (more) negative interest rates are consequently applied, users may feel negatively surprised by such changes, notwithstanding related disclosures that this could occur. If holding CBDC became an exercise in active management of interest rate risk, any public benefits tied to wide access and inclusivity may be thwarted. There may also be negative economic and confidence-reducing effects associated with widely applying increasingly negative rates to household wealth in a time of stress.

5.2 Measures to manage bank run risk

In the absence of any sufficiently binding CBDC constraints,[16] periods of stress could require additional safeguards, over and above prevailing deposit insurance and crisis management frameworks in order to avoid or slow bank runs into a CBDC.

Prudential regulation is continually under review as the liquidity of bank deposits and other liabilities changes over time, for example due to technological innovations. The introduction of a CBDC or new forms of private money such as stablecoins could affect the latent risk of systemic runs, and banks may also need to adapt their own practices (Juks (2018)). For example, in the current LCR regulations, the outflow parameters for deposits provided by retail and small business customers were calibrated based on observed outflow rates during stress times that, by definition, do not account for the impact on depositors' stress behaviour in the presence of a CBDC or certain new private forms of digital money. If the introduction of CBDC increased the outflow risk for such deposits, the corresponding outflow rates may need to be reassessed to ensure that enough liquidity is available to cover potential outflows in times of stress.

[15] A waterfall mechanism would enable "excess" holdings of CBDC, arising from incoming payments that bring account holdings above a holding limit, to be automatically transferred to an account held at a bank or another intermediary.

[16] For example, in crises times price-based safeguards might be insufficiently effective because there could be no price (or only a very high price) at which individuals would be willing to hold deposits instead of CBDC.

Authorities may also need faster-acting crisis management tools. The potential for a CBDC or new private forms of digital money to increase the pace of bank runs may also necessitate examining crisis measures such as limits or controlling fund outflows from bank deposits. Central bank emergency liquidity frameworks could also be reviewed, for example to broaden collateral or access.

5.3 Other safeguards

To the extent that the introduction of CBDC or new private forms of digital money introduce new policies, regulations, rules, or new competitive advantages in service provision by different players, new concentrations of service provision may arise. Central banks should be confident that regulatory and supervisory frameworks will facilitate effective monitoring and regulation as the system evolves.

6. Conclusions

This report has focused primarily on potential risks to financial stability that could arise from the introduction of a CBDC and how to mitigate these risks. These risks need to be considered alongside the benefits and counterfactuals. A CBDC has the potential to offer new opportunities for innovation, which may benefit banks, and non-bank/third-party providers of financial services, supporting a competitive and diverse financial system. This could facilitate new opportunities for innovation and increase the resilience of the system overall – subject to authorities ensuring appropriate regulation of all parties. At the same time there is also continuing change in payment methods and emergence of new forms of privately issued digital money, some of which pose risks themselves.

The introduction of a CBDC could prompt some changes that affect the functioning of the financial system in ways similar to the introduction of new forms of private money such as stablecoins. The extent and nature of these changes would depend on take-up, which remains highly uncertain and depends on design features and attractiveness relative to deposits. The choice of a remuneration approach, and competitiveness with bank deposits, would likely be a key factor determining take-up, but non-pecuniary factors ranging from privacy to payments access could be important as well. Potential benchmarks for take-up would include factors that are specific to each jurisdiction, such as the payment attitudes and volume of currency in circulation.

A material shift from bank deposits to CBDC – which would be possible for example if the holdings of CBDCs by individual users were left unconstrained – could have a non-trivial, long-term impact on bank lending and intermediation, although these impacts may be limited for many plausible levels of CBDC take-up and if the system has time to adjust. Estimates from a simple, partial model suggest that a large shift from bank deposits to CBDC could plausibly lead to a fall in bank profitability in benign circumstances, assuming normalized monetary conditions. This could in turn affect lending conditions and/or the resilience of banks. It could imply more reliance by banks on wholesale market funding. Greater take-up levels would have a greater impact on the financial system. Moreover, the impact could be exacerbated if the response of the banking system strains the capacity of funding markets. This is more likely to occur if deposits were lost over a shorter time frame. The implications could also be larger for some types of bank business model than others.

In the context of negative interest rates, decisions around whether and how to remunerate a CBDC become more complex, given the presence of unremunerated cash, and potential

competition with bank deposits or money instruments with negative interest rates. Given the prevalence of negative interest rates and current proximity to the zero-lower bound in many jurisdictions, issues related to negative interest rates require further consideration.

Yet additionally, the existence of unconstrained CBDCs, or other digital money, as an easily accessible, safe asset could increase the risk of systemic banks runs and make money market funds or instruments more susceptible to abrupt outflows. A similar effect could arise for other sectors seen as relatively safe, notably in money markets.

That said, the presence of a CBDC could, over time, increase diversity of providers of payments and other financial intermediation services. The introduction of a CBDC could make it easier for new financial service providers to enter the market for payments services or to improve the competition amongst banks and non-banks for lending – increasing the diversity of financial service provision. This in turn, subject to appropriate regulation of all participants, could increase the resilience of financial service provision to shocks and reduce the impact of financial crises overall.

Central banks can introduce safeguards in a CBDC framework to reduce financial stability risks, notably by limiting take-up permanently or on a transitional basis. Financial stability risks also need to be carefully considered for private digital money and are potentially more challenging to manage than for CBDC. Depending on the specific rationale in a jurisdiction for pursuing CBDC, combinations of limits on CBDC holdings or transactions, or remuneration disincentives, could be deployed to moderate take-up. Calibration of limits or remuneration frameworks would need to balance moderating the take-up of CBDC, specifically substitution with private money and deposits, with allowing a CBDC to fulfil its public policy objectives. Technical solutions that allow for monitoring and implementation of limits would also need to be considered in the design phases of a CBDC, and some safeguards may be easier to implement than others.

A CBDC (or certain new forms of privately issued digital money) could also change run dynamics in a stress, and the latent level of liquidity risk banks face. Authorities might need to consider adjusting prudential liquidity requirements or other measures such as the terms of their crisis lending facilities. The potential for more abrupt flows out of money market instruments may also demand further consideration of prudential regulation in that sector. And to the extent that CBDCs encourage new entrants and the growth of non-bank financial services, authorities would need to ensure appropriate regulation of these entities.

Overall, considerable further work is needed to fully understand the full range of effects and quantify the implications for financial stability from CBDCs (including the risks and also the opportunities to enhance financial stability as the payments landscape continues to evolve), and the various design, remuneration and safeguard options. The novelty of a CBDC creates many difficult to answer questions around firstly, the extent of potential take-up, and secondly how banks, nonbanks and other providers might react to its introduction. Initial, illustrative analysis has helped shed some light on partial responses to changes in bank funding, but they have also revealed that more consideration is needed of when behavioural responses could lead to bigger impacts, and when offsetting affects might appear. Furthermore, much attention to date has been focused on risks to banks, and more consideration of the impact on money markets may be worthwhile. Observations from early CBDC launches and pilot schemes could be useful in providing more information.

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Annex A: Details of the model

Main analysis

We analyse the impact of introducing a CBDC. We assume that introducing a CBDC leads to an outflow of deposits from the banking system. This means that deposits are subtracted from the liabilities side of the banking system balance sheet, and an equivalent amount of reserves (some of their HQLA) are subtracted from the assets side of their balance sheet.

In the first, second and third rows of Table 1.A, we calculate LCR before CBDC is introduced, after CBDC is introduced but before banks take any action, and after banks adjust their HQLA, respectively.

Impact of a CBDC on the LCR and liquid assets needed to maintain the LCR — Table 1.A

Time	**LCR**	**Definition of variables**
Before deposit outflow to CBDC	$LCR_{pre} = \frac{X}{Y}$	X represents HQLA Y represents LCR stressed outflows
After deposit outflow, before banks take any action	$LCR_{interim} = \frac{X - D}{Y - sD}$	D represents deposit outflow to CBDC s represents the LCR stress factor on those deposits
After deposit outflow and banks acquiring new HQLA	$LCR_{post} = \frac{X - D + L}{Y - sD}$	L represents HQLA acquired after deposit outflow

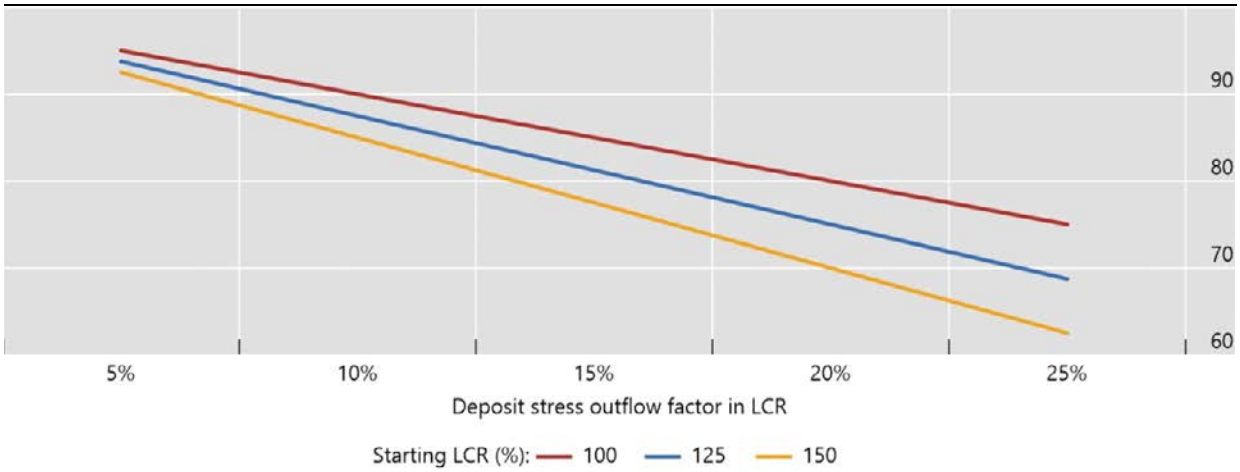
We assume that banks acquire new HQLA to maintain their actual LCR (including any management buffer over regulatory requirements) after deposit outflow. To maintain LCR at its initial level, ie $LCR_{post} = LCR_{pre}$, we must have:

$$L = D(1 - s.LCR_{pre})$$

This equation states that the additional HQLA needed to maintain the LCR at the level prior to deposit outflow to the CBDC is a function of the size of the deposit outflow (D), the stress outflow factor of those deposits (s), and the starting LCR. Graph 1.A below illustrates the amount of HQLA relative to the deposit outflow, ie L/D, needed to maintain the LCR for stress deposit outflow factors from 5% to 25% (a typical range for retail deposits) and starting LCRs from 100% to 150% (as some banks will hold excess liquid buffers).

HQLA needed to maintain LCR relative to deposit outflow

HQLA relative to deposit outflow ratio, in percent — Graph 1.A



Sources: Working Group

In this example, the HQLA needed to maintain the LCR is between around 60% and 95% of the deposit outflow. For example, a deposit outflow of USD100 billion would need USD60-95 billion of additional HQLA to maintain the LCR.

Impact of banks' actions to maintain LCRs on their balance sheet and profitability measures

One way banks could maintain their LCRs (and net stable funding ratios) is to buy HQLA in the form of government bonds, funded by long-term (eg more than 2 years) wholesale debt issuance which would have a zero stress outflow factor in the LCR. Table 2.A describes how such an action would impact on banks' balance sheets.

Impact on banks' balance sheets if banks maintain LCRs — Table 2.A

	Change in assets and liabilities
Initial change in banks' reserve asset and deposit liability	$-D$
Banks' purchase of HQLA funded with long-term wholesale debt	$D(1-s\frac{X}{Y})$
Net change in size of banks' balance sheet	$-D.s.\frac{X}{Y}=-D.s.LCR_{pre}$

This analysis shows that banks' balance sheets would contract by a small amount rather than remain constant. The intuition for this is that banks do not need to replace all the central bank reserves that left the banking system because they had already held some of those reserves against the deposits that have left the banking system. If for example, $100bn deposits left the banking system then for the stressed outflow and starting LCRs in Graph 1.A, the banking system would contract by around $5-40bn, which is small relative to the size of the banking system.

Next, we calculate how banks' net interest income (NII), NIM and RoE change if they adopt the aforementioned measures, ie buying HQLA against long-term wholesale funding, while keeping LCR fixed

at the level prior to introducing a CBDC. For this, we start by introducing a simplified banks' balance sheet below:

Balance sheet of the banking system before CBDC

interest earned	Assets			Liabilities		interest paid
r_1	HQLA	A_1	L_1	Deposits		i_1
r_2	Loans	A_2	L_2	Wholesale funding		i_2
r_3	Other	A_3	C	Capital		

We can write the NII, NIM, RoE and return on assets (RoA) as follows:

$$NII_{pre} = (r_1 A_1 + r_2 A_2 + r_3 A_3) - (i_1 L_1 + i_2 L_2)$$
$$NIM_{pre} = \frac{NII_{pre}}{A}$$
$$RoA_{pre} = \frac{NII_{pre}(1-T)}{A}$$
$$RoE_{pre} = \frac{NII_{pre}(1-T)}{C}$$

where $A \equiv A_1 + A_2 + A_3$ is the total amount of assets, RoE is calculated post-tax, and T is the tax rate for banks.[17]

After CBDC is introduced and banks acquire HQLA against long-term wholesale funding (including secured and unsecured), their balance sheet turns into the following:

Balance sheet of the banking system after CBDC

Assets		Liabilities	
HQLA	$A_1 - \mathrm{D.s.LCR}_0$	L_1-D	Deposits
Loans	A_2	$L_2 + \mathrm{D}(1 - \mathrm{s.LCR}_0)$	Wholesale funding
Other	A_3	C	Capital

Again, we can calculate new values of NII, NIM, RoE and RoA as follows:

$$NII_{post} = \Big((r_1 + dr_1)\big(A_1 - D.s.LCR_{pre}\big) + r_2 A_2 + r_3 A_3\Big)$$
$$-((i_1 + di_1)(L_1 - D) + (i_2 + di_2)(L_2 + D(1 - s.LCR_{pre}))$$
$$NIM_{post} = \frac{NII_{post}}{A - \mathrm{D.s.}LCR_{pre}}$$
$$RoA_{post} = \frac{NII_{post}(1-T)}{A - \mathrm{D.s.}LCR_{pre}}$$
$$RoE_{post} = \frac{NII_{post}(1-T)}{C}$$

[17] To calculate NIM, we need to divide NII by total interest-bearing assets, but here, we assume all assets are interest bearing, so total assets and total interest-bearing assets are identical.

Next, we calculate the change in these profitability measures one by one. Before that, we show the variable names, values, parameters, and source of data in Table 3.A. We do not have consistent data across all parameters for developed countries, but we believe that the results are useful to illustrate the potential impact. The analysis can also be replicated by individual country.

Model variable names, values, parameters, and source of data Table 3.A

Variable name	**Value**	**Parameter**	**Source**
Spread between HQLA and deposit rates	0.00%	$m_b = r1 - i1$	Average of the spread between repo rate and deposits (3-month) for banks of G7 plus Switzerland for 2010-2020, from BIS
Loans to assets	58.00%	A_2/A	Average across countries for 2016, from BIS (CGFS publication, Table 1.10)
Net Interest Income	3.52%	NII/A	Average of NII to interest-earning assets, for banks in G7, Sweden and Switzerland for 2010-2020, from BIS
Return on equity	7.50%	RoE	Average of RoE for 2016 from BIS dataset (CGFS publication, Table 1.27)
Net Interest Margin	2.30%	NIM	Simple average across countries for 2016 from BIS dataset (CGFS publication, Table 1.30)
Deposits stress factor	15%	s	Broadly representative of a blend of retail and corporate deposits
Liquidity Coverage Ratio	125%	LCR	Broadly representative of the US and European banks
Spread between 5-year wholesale and deposit rates	0.63%	m_a	Average over 2017-2021 across G7 (excluding US) plus Sweden

Impact on NII

$$\Delta NII = NII_{post} - NII_{pre} = -r_1 D.s.LCR_{pre} + i_1 D - i_2 D\left(1 - s.LCR_{pre}\right)$$
$$+dr_1(A_1 - D.s.LCR_{pre}) - di_1(L_1 - D) - di_2\left(L_2 + D\left(1 - s.LCR_{pre}\right)\right)$$

where:

dr_1, di_1 and di_2 denote the change in r_1, i_1 and i_2, respectively.

For the rest of the analysis, we assume $dr_1 = di_1 = di_2 = 0$.

That is, the rates do not change following the introduction of a CBDC. Using our framework, it is easy to do various sensitivity analyses for the cases that rates change too.

Given this assumption, we can write:

$$\Delta NII = D\left((i_1 - i_2) - s.LCR_{pre}(r_1 - i_2)\right) = D\left(-m_a - s.LCR_{pre}(m_b - m_a)\right)$$
$$= -\left[\left(1 - s.LCR_{pre}\right)m_a + s.LCR_{pre}.m_b\right]D$$

where:

$m_a \equiv i_2 - i_1$ denotes the spread between wholesale and deposit funding rates, and
$m_b \equiv r_1 - i_1$ denotes the spread between HQLA and deposit rates.

Equivalently:

$$\frac{\Delta NII}{NII} = -\left[\left(1 - s.LCR_{pre}\right)m_a + s.LCR_{pre}.m_b\right]\frac{D/A}{NII/A}$$

In the numerator, we have the initial, relative change in the size of the balance sheet, and in the denominator, we have the net interest income relative to the size of the balance sheet.

Impact on RoE

$$\Delta RoE = \frac{1 - T}{C}\Delta NII = RoE_{pre}\frac{\Delta NII}{NII_t}$$

Like previous figures, Figure 3 illustrates the change in the RoE.[18]

Impact on NIM

$$\frac{NIM_{post}}{NIM_{pre}} = \frac{\frac{NII_{post}}{NII_{pre}}}{\frac{A - \mathrm{D.s.}LCR_{pre}}{A}} = \frac{1 + \frac{\Delta NII}{NII_{pre}}}{1 - \frac{\mathrm{D.s.}LCR_{pre}}{A}}$$

If $\frac{\mathrm{D.s.}LCR_{pre}}{A}$ is small, we will have:

$$\Delta NIM = NIM_{pre}\frac{NIM_{post} - NIM_{pre}}{NIM_{pre}} \cong NIM_{pre}\left(\frac{\Delta NII}{NII_{pre}} + \frac{\mathrm{D.s.}LCR_{pre}}{A}\right)$$

[18] Note that from a bank examiner's point of view, RoA might be more important than RoE, as the latter is more relevant to equity holders not to the regulator. However, in our framework, the percentage change in RoA is equal to the percentage change in the NIM, so we don't report results for RoA separately.

Potential impact on loan rates

In this section, we examine the case in which banks aim to maintain their NII (equivalent approximately to maintaining their NIM, as NIM denominator changes slightly) by changing their loan rates. Crucially, we assume that lending volumes could be maintained. This assumption is not realistic, but the goal is to get a sense of the size of change in the lending rates, not to predict the exact change.

Denote by x the increase in the loan rate needed to maintain NII. Then, x is given by

$$\Delta NII = D\big((i_1 - i_2) - s.LCR_t(r_1 - i_2)\big) + xA_2 = 0, \text{ so}$$
$$x = \big[(1 - s.LCR_{pre})m_a + s.LCR_{pre}.m_b\big]\frac{D}{A_2}$$

The first term relates to the cost of the switch in funding from deposits to wholesale funding. The second term relates to the cost of the slight reduction in HQLA needed for the new steady state balance sheet, if the HQLA rate is above the deposit rate (ie if bank deposit rates are below the central bank policy rate). This is small if the outflow factor s is small and/or if the deposit spread to the policy rate is small.

The lines in Graph 3 (in the main report) are relatively insensitive to plausible variations in s, LCR and the spread between deposit rates and the policy rate (m_b). To adjust for term premia, we can assume that the long-term wholesale funding rate and loan rates are floating rate (including fixed rate funding/loans that are swapped into floating).

In these illustrations, the maximum impact on loan rates is around 0.7% pts for a deposit outflow of 25% relative to the size of the assets and if the wholesale funding rate is 2% pts higher than the deposit rate.

Annex B: Expert group members

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Board of Governors of the Federal Reserve System	Melissa Leistra
Bank for International Settlements	Giovanni Lombardo

Thanks also go to Katie Fortune (Bank of England).