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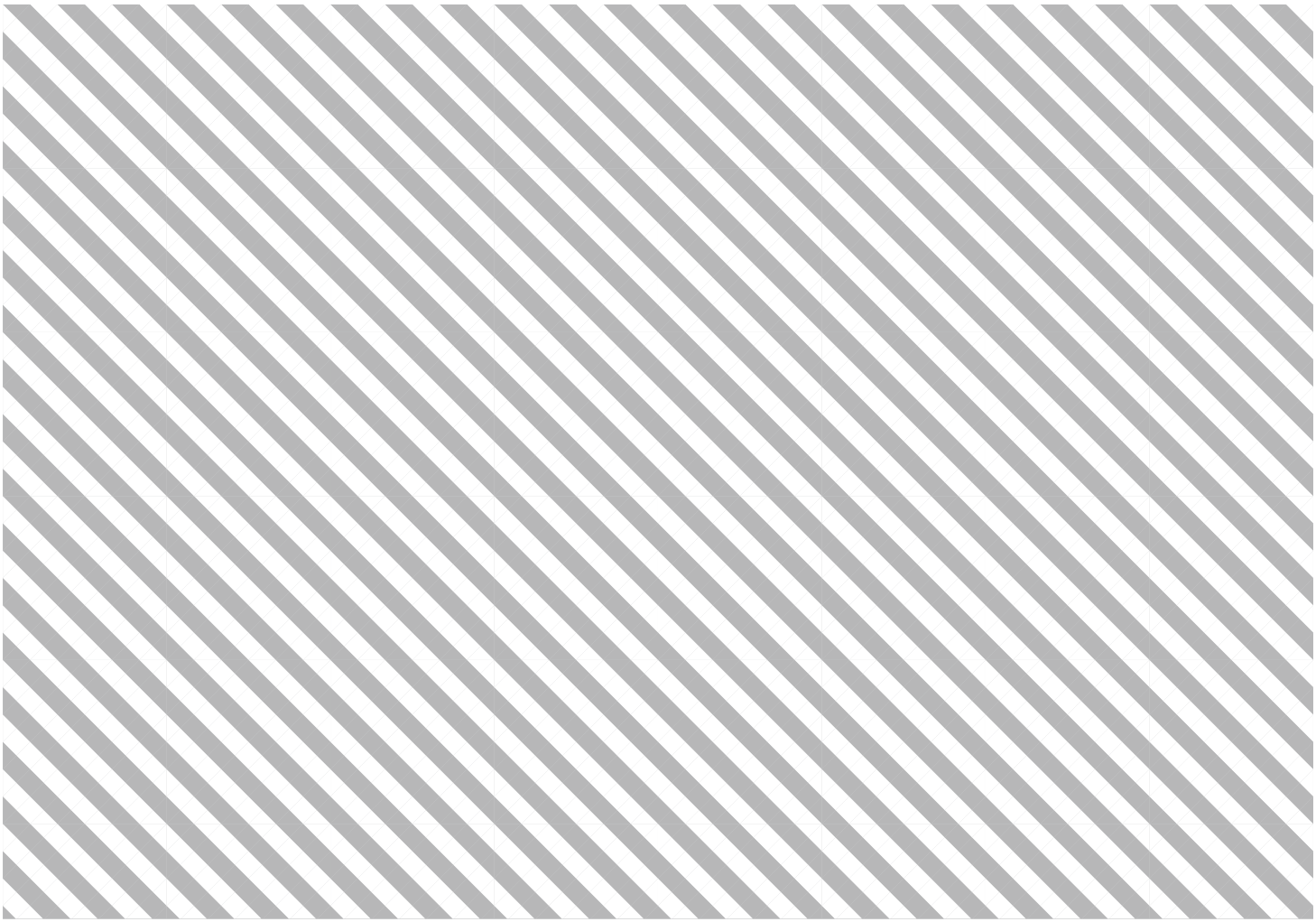
White Paper

Central Banks and Distributed Ledger Technology: How are Central Banks Exploring Blockchain Today?

March 2019



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Contents

Foreword 4

Part 1: Research, experimentation, and early implementations 5

- Research and experimentation 5
- Early implementations 6
- 10 use cases for central banks with DLT 7

Part 2: An introduction to central bank digital currency 8

- The “money flower” 8
- Retail CBDC: key benefits and downsides 9
- CBDC design and implementation trade-offs 10
- Where is wholesale CBDC research focused today? 11
- Alternative payment systems 12
- CBDC and geopolitical manoeuvring 12

Conclusion 13

Foreword

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According to a January 2019 report by the Bank for International Settlements (BIS) in Basel, Switzerland, at least 40 central banks around the world are currently, or soon will be, researching and experimenting with central bank digital currency (CBDC).

CBDC, a commonly proposed application of blockchain and distributed ledger technology (DLT), has attracted much interest within the central banking community for its potential to address long-standing challenges such as financial inclusion, payments efficiency, and payment system operational and cyber resilience. Including but not limited to CBDC, central banks are researching and experimenting with at least 10 specific use cases for blockchain and DLT, exploring where they can potentially unlock new possibilities and improve inefficient processes.

While central banks across continents are conducting several research projects and pilots with blockchain technology, the degree of depth, progress and interest across efforts varies greatly. In rare cases, such as with the Bank of France, the central bank has already fully deployed blockchain technology.

Central bank activities with blockchain and DLT are not always well known or communicated. As a result, there is much speculation and misunderstanding about objectives and the state of research. The purpose of this paper is to introduce and highlight the key issues and areas of research, experimentation and implementation for central banks with respect to DLT. Importantly, DLT is an active area of research and exploration, and many central banks have not yet reached definitive conclusions regarding the opportunities it provides when considering risks.

How are central banks researching blockchain technology today and why?

Part 1:
Research, experimentation and early implementations

Research and experimentation

The degree of blockchain technology research and experimentation varies greatly among central banks, as do the motivations for interest. Some central banks are progressive, having begun research and experimentation as early as 2014 and having conducted multiple pilots or even deployments. Another set of institutions is curious and interested in the technology but largely monitors activity by peer institutions and within the private sector, including cryptocurrency investing activity. A final set has not yet dedicated resources to blockchain technology research and may never do so, either because of pressing priorities or the view that DLT at this stage does not promise sufficient upside when considering technological immaturity and risks.

The World Economic Forum curates a list of more than 60 major reports, white papers, or speeches from central bank researchers, international organizations, or research economists on the subject of blockchain and DLT for central bank processes and macroeconomics. The list includes the references in this report and serves as a resource for identifying central bank research on DLT.

The Bank of Canada, the Bank of England, and the Monetary Authority of Singapore (MAS) stand out as having published multiple in-depth research reports or having conducted multiple technology pilots with DLT. The Bank of England was the first central bank to publish research on DLT, starting in 2014 with the papers, "*The economics of digital currencies*" and "*Innovations in payments technologies and the emergence of digital currencies*". The Bank of Canada's Project Jasper and the MAS's Project Ubin pilots investigate how CBDC can be applied to improve efficiency, performance and resilience in domestic interbank payments.

Most recently, in November 2018, these three central banks published one of the first multilateral research papers on DLT, titled, "*Cross-border interbank payments and settlements*". Meanwhile, the European Central Bank (ECB) and the Bank of Japan conducted a joint pilot, Project Stella, beginning in 2016, which explores whether the technology can improve domestic interbank payments and settlements (phase 1) and facilitate rapid interbank trading and settlement of securities for cash (phase 2).

How is CBDC implemented in pilots?

In many of these CBDC pilots, the central bank issues digital tokens on a distributed ledger that represent, and are redeemable for, central bank reserves in the domestic currency held in a separate account with the central bank. The agents in the system use the CBDC to make interbank transfers that are validated and settled on the distributed ledger.

The central banks typically use "permissioned" blockchain network implementations, whereby participants are limited and must be granted access to participate in the network and view the set of transactions. In contrast, major "permissionless" blockchains, such as Bitcoin and Ethereum, allow public participation and full transaction viewability. Both permissioned and permissionless networks can add privacy and confidentiality features to mask transaction details where appropriate.

The central bank chooses, according to suitability and availability, the type of network and its internal mechanisms (most importantly, the decentralized consensus mechanism the network uses for participants to reach agreement on valid transactions). R3's Corda, the Linux Foundation's Hyperledger Fabric, J.P. Morgan's Quorum, or a simple private configuration of the Ethereum blockchain network are the most popular implementations used by central banks.

Additional institutions conducting projects with blockchain technology include the following:

- The Bank of Lithuania is planning to issue "Digital Collector Coin" to test blockchain in a small-scale and real environment. It will be linked to physical collector coins kept in the Bank of Lithuania's vaults. The bank is also sponsoring a blockchain sandbox called LBChain.
- The Bank of Thailand is exploring CBDC for interbank payments and liquidity management efficiency with Project Inthanon.
- The Central Bank of Brazil is exploring DLT for an interbank payments contingency and resiliency system (Project SALT) as well as a decentralized information exchange platform (Project PIER).
- The Eastern Caribbean Central Bank is exploring the suitability of a DLT-based Eastern Caribbean currency to pursue multiple goals such as advancing economic growth, payments system resilience and financial inclusion.
- The German central bank (Deutsche Bundesbank) is exploring DLT for multiple purposes including for improving efficiency and reducing risk in interbank securities settlement processes with the BLOCKBASTER prototype and other efforts.
- The Hong Kong Monetary Authority conducts research and experiments on multiple use cases including trade finance, digital identity management and KYC/AML processes.
- The Saudi Arabian Monetary Authority is conducting Project Aber with the United Arab Emirates to pilot DLT for interbank payments and settlements between Saudi Arabia and the UAE.
- The South African Reserve Bank is exploring CBDC for domestic interbank payment and settlement efficiency with Project Khokha.
- The Swedish central bank (Sveriges Riksbank) is investigating a blockchain-based "e-krona" to serve as an alternative form of central bank-issued money as cash usage in the country declines. Of note, the Swedish central bank has not yet determined whether, if it implements an ekrona, it will employ DLT.

Early implementations

While research and innovation with blockchain technology have been under way for the past several years, few organizations have actually deployed the technology. Although central banks are among the most cautious and prudent institutions in the world, they are, perhaps surprisingly, among the first to implement blockchain technology.

The Bank of France
The Bank of France, with project MADRE, has fully replaced its centralized process for the provisioning and sharing of SEPA Credit Identifiers (SCIs) with a decentralized, blockchain-based solution. The project began as a proof-of-concept in June 2016 to learn more about DLT with a simple use case. The central bank identified an opportunity where DLT could be valuable to automate and digitize a manual and time-intensive process that requires coordination and information sharing with multiple banks.

The alternative system decentralizes and automates the SCI management and sharing process with "smart contracts" or programmes within Ethereum and other blockchains that enable automatic transactions among participants using predetermined terms. Today, smart contracts are used to issue 100% of the SCIs in the system.

The Bank of France considers the implementation a success. In addition to greater time efficiency, it cites benefits such as process auditability and disaster recovery, along with greater accountability for commercial banks within the process.

What is SEPA?

The single euro payments area (SEPA) is a payment scheme created by the European Union that seeks to achieve an integrated market for payments in the euro area. It facilitates fast, efficient and secure cross-border direct debit and credit transfers and card payments across European countries. It is operationalized on a country-by-country basis, and central banks manage the process in coordination with domestic commercial banks.

The National Bank of Cambodia
In a second example, the National Bank of Cambodia will be one of the first countries to use blockchain technology in its national payments systems for use by consumers and commercial banks. It is implementing blockchain technology in the second half of 2019 as an experiment to support both financial inclusion and greater banking system efficiency.

Cambodia's underbanked populations use cash (both in US dollars and Cambodian riel) and a variety of mobile-phone based private payment applications to store and send money between each other and businesses. Retail savings and payments are fragmented and citizens are unable to reliably save money in mobile phone-based accounts. They also have difficulty transferring money to those who use a different mobile money application from themselves.

The new blockchain-based payment system, in which consumers gain access via participating commercial banks, is designed to operate both with private mobile payment applications and commercial bank accounts, facilitating interoperable retail payments between citizens and businesses and encouraging citizens to adopt bank accounts, which support savings and financial stability.

Furthermore, Cambodia's domestic interbank system lacks highly efficient payments and settlements processes. This opens the window for experimentation to improve upon and potentially "leapfrog" traditional wholesale interbank processes. As with France, economies that are similar to Cambodia's in the ASEAN region which observe the National Bank of Cambodia's implementation may identify opportunities for themselves to use such DLT applications to enhance financial inclusion and banking-sector efficiency.

Ten use cases for central banks with distributed ledger technology

The following is a non-exhaustive list of DLT applications or use cases which at least one central bank is actively researching.

1	**Retail central bank digital currency (CBDC)** – Central bank-issued digital currency that is operated and settled in a peer-to-peer and decentralized manner (no intermediary), widely available for consumer use. Serves as a complement or substitute for physical cash and alternative to traditional bank deposits.
2	**Wholesale central bank digital currency (CBDC)** – Central bank-issued digital currency that is operated and settled in a peer-to-peer and decentralized manner (no intermediary), available only for commercial banks and clearing houses for use in the wholesale interbank market.
3	**Interbank securities settlement** – A focused application of blockchain-based digital currency, including CBDC, enabling the rapid interbank clearing and settlement of securities for cash. Can achieve "delivery versus payment" interbank systems where two parties trading an asset, such as a security for cash, can conduct the payment for and delivery of the asset simultaneously.
4	**Payment system resiliency and contingency** – The use of DLT in a primary or back-up domestic interbank payment and settlement system to provide safety and continuity from threats, including technical or network failure, natural disaster, cybercrime, and other threats. Often, this use case is coupled with others as part of the set of benefits that a DLT implementation could potentially offer.
5	**Bond issuance and lifecycle management** – The use of DLT in the bond auction, issuance, or other lifecycle processes to reduce costs and increase efficiency. May be applied to bonds issued and managed by sovereign states, international organizations or government agencies. Central banks or government regulators could be "observer nodes" to monitor activity where relevant.
6	**Know-your-customer and anti-money-laundering** – Digital KYC/AML processes that leverage DLT to track and share relevant customer payment and identity information to streamline processes. May connect to a digital national identity platform or plug into pre-existing e-KYC or AML systems. Could potentially interact with CBDC as part of payments and financial activity tracking.
7	**Information exchange and data sharing** – The use of distributed or decentralized databases to create alternative systems for information and data sharing between or within related government or private sector institutions.
8	**Trade finance** – The employment of a decentralized database and functionality to enable faster, more efficient and more inclusive trade financing. Improves on today's trade finance processes which are often paper-based, labour-intensive and time-intensive. Customer information and transaction histories are shared between participants in the decentralized database while maintaining privacy and confidentiality where needed.
9	**Cash money supply chain** – The use of DLT for issuing, tracking and managing the delivery and movement of cash from production facilities to the central bank and commercial bank branches; could include the ordering, depositing or movement of funds, and could simplify regulatory reporting.
10	**Customer SEPA Creditor Identifier (SCI) provisioning** – Blockchain-based decentralized sharing repository for SEPA credit identifiers managed by the central bank and commercial banks in the SEPA debiting scheme. Faster, streamlined and decentralized system for identity provisioning and sharing. Can replace preexisting manual and centralized processes that are time and resource-intensive. Seen in Bank of France's Project MADRE implementation.

Importantly, blockchain technology could enable new capabilities for central bank processes that have not yet been identified. As central banks evaluate the technology and applications, they should evaluate not only how it could function within today's context of central bank money and monetary functionalities but also how it could potentially enable new processes and functionalities. Of course, central banks must consider the risks and downsides of DLT implementations, which can include new security, scalability and usability risks as well as unforeseen risks.

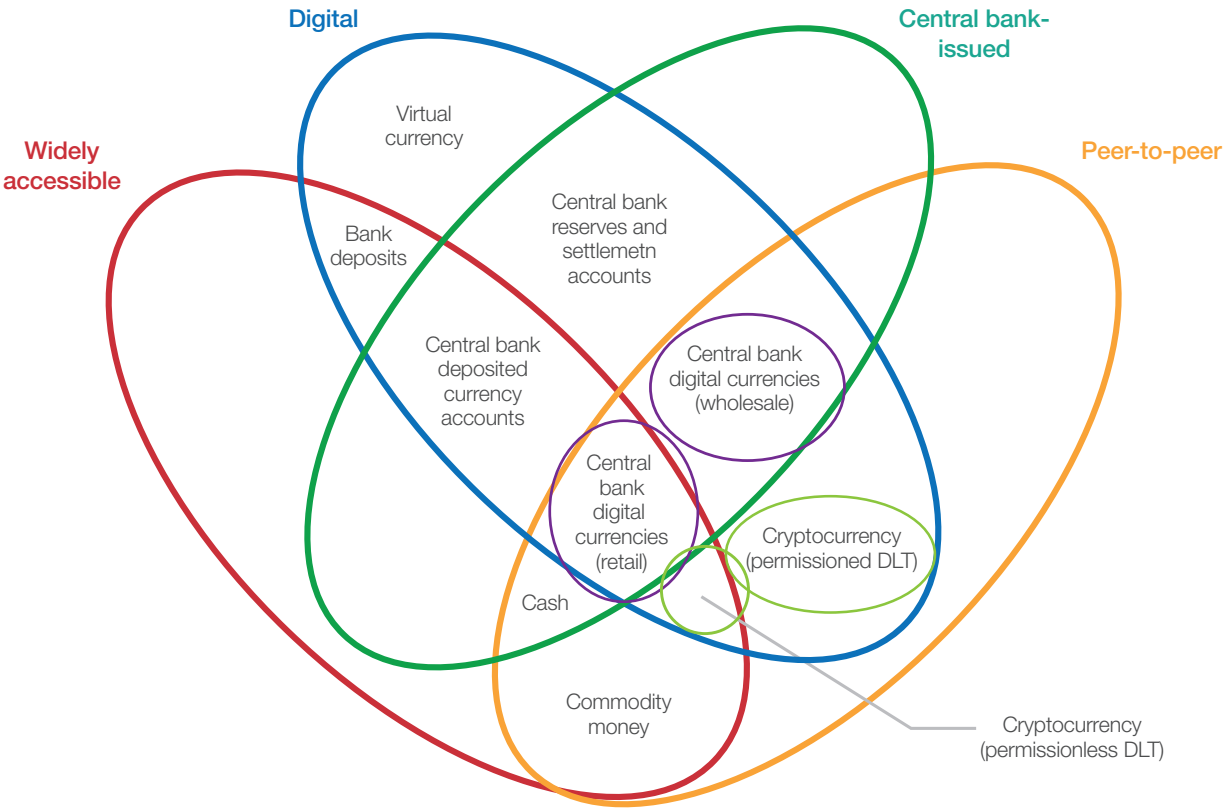
Part 2:
An introduction to central bank digital currency (CBDC)

CBDC is a potential application of blockchain and distributed ledger technology (DLT) where the central bank issues new money equivalent to – and redeemable for – its domestic currency, often simultaneously removing the equivalent amount of currency from the money supply. It may be issued for general use ("retail" CBDC) for peer-to-peer payments and payments from consumers to merchants, or for use by commercial banks and clearing houses ("wholesale" CBDC) for more efficient interbank payments that occur outside traditional correspondent banking and other payment systems.

The 'money flower'

The following "money flower" is employed in several reports on CBDC to help define CBDCs relative to other forms of money. The two subjects circled in purple represent retail and wholesale CBDC, while the two subjects circled in green represent privately issued cryptocurrency such as bitcoin and ether, in either a publicly accessible "permissionless" form or a privatized "permissioned" form.

Figure 1: The money flower: a taxonomy of money



Sources: Adapted from M Bech and R Garratt, "Central bank cryptocurrencies", BIS Quarterly Review, September 2017, pp 55-70;
As seen in "Cryptocurrencies: looking beyond the hype", BIS Annual Economic Report 2018 , p 94.

Of note, central banks already issue money in digitized form today. CBDC, by contrast, is typically issued on distributed ledgers where it can be transacted in a peer-to-peer manner, facilitating more rapid or cost-efficient transactions in some contexts. Further, central banks have already conducted research on the notion of citizens holding deposits directly in central bank accounts, known as "central bank deposited currency accounts" on the left side of the "money flower". Ecuador's *Dinero Electrónico* is an example, although it closed after about three years of use, partly form low adoption (it did not employ DLT). Central banks consider these precedents that do not use DLT in their evaluation of CBDC issuance.

For further reference, pages 7-8 of the 2017 BIS report, "Central bank cryptocurrencies", maps real-world digital currency experiments and implementations from various countries on to the "money flower" model.

Retail CBDC: key benefits and downsides

The table below summarizes some of the noteworthy benefits and downsides to retail CBDC that are discussed in research today. It is imperative for policy-makers and researchers to deeply consider all risks and downsides to implementation within the specific country context and to weigh benefits with risks and downsides. For instance, rarely discussed in CBDC research is the potential for financial exclusion rather than inclusion. Policy-makers must seek to encourage the unbanked to participate in any new digital currency regime. They must be aware of hurdles to adoption such as usability challenges, access, or insufficient government identity documentation.

A second notable risk relates to stability in commercial bank deposits, as citizens may see CBDC held in accounts with the central bank as a safer or more attractive substitute for holding money in deposits at a commercial bank. If citizens switch to holding money in CBDC, commercial bank deposits could become more volatile and volumes could decrease, which would cause instability in commercial bank balance sheets and a potential reduction in lending activity. These risks can be addressed through implementation decisions described in the next section, namely decisions around interest payments on CBDC and account and transaction size limits.

Moreover, CBDC can potentially play an important role in a future where cash usage dramatically declines. If the use and availability of cash within a country becomes extremely low or non-existent, whether by policy or consumer preferences, then CBDC could potentially aid citizens.

In this environment, in countries where commercial banks are unstable and deposit insurance is not offered, CBDC accounts with the central bank could provide a potentially safe place for citizens to save money (account size limits notwithstanding). Second, they could help citizens maintain direct access to central bank money (cash, today). Third, CBDC, and any central bank-issued mobile phone applications that could accompany it, could serve as an important alternative and counterweight to private sector digital payments applications that could dominate in a country.

Ultimately, as stated by economist Ousmène Mandeng in a recent speech entitled, "Do central banks need to issue currency?": "*The case for CBDC should naturally rest on whether it supports central banks' and the public's objectives*."

Pros	Cons
Potential for faster and cheaper domestic and cross-border payments (both retail and wholesale)	Notable risks to financial stability from bank disintermediation or other forces
Potential to offer retail depositors safer savings venue (i.e., accounts with the central bank) with lower risk of default or loss of funds than storing savings in domestic commercial bank accounts (varies by country)	Relative to physical cash, introduces noteworthy consumer privacy and protection risks
Potential to improve payment system resilience to cyberattacks, operational failures and hardware faults relative to centralized data storage and processing, which has less data redundancy and, therefore, may be less robust	Relative to physical cash, increases exposure and vulnerability to cyber-security risk and power outages
Potential to provide alternative to private sector digital payments technologies, to counter operational risk or monopolistic control by those providers if they become dominant, and to serve as a government-issued alternative for cash if it becomes scarce in the future	Blockchain technology challenges: transaction scalability, user experience, key management, confidentiality and transaction speeds
Potential to incentivize participation in banking sector for the under-banked	Potential for financial exclusion if populations who do not adopt CBDC are not integrated and are further marginalized from digital payment systems
Potential to improve AML/KYC functionalities and to reduce tax evasion, corruption and illicit activities (often not a primary area of focus for a central bank)	Potential for sovereign to have greater access to appropriate citizen funds (for any form of money custodied with the central bank)
Potential to reduce frictions and costs associated with physical cash storage, transport and management within the banking system	Introduces unknown risks
Potential to challenge commercial bank monopoly power of retail deposits; can pressure commercial banks to increase interest rates to depositors and provide more financial services; may also be a risk to financial system stability	

CBDC design and implementation trade-offs

Central banks also consider key design and implementation choices when evaluating the prospect of retail or wholesale CBDC. The following is a cursory list of some of the major trade-offs and choices they evaluate.

- **Availability**: Should the CBDC be available for public use (retail CBDC), or restricted for commercial banks and clearing houses (wholesale)? Who is the primary audience of the CBDC, retail consumers and citizens, or commercial banks?

- **Distribution and storage**: If CBDC is for retail use, what is the distribution mechanism that is most effective, achieves the program's goals, and is the most inclusive to capture all eligible participants? Further, where will the CBDC be held? CBDC can either be held in accounts directly at the central bank, in accounts at participating commercial banks if they act as intermediaries for distribution, or on government-issued debit cards, among other options.

- **Interest payments**: Should the central bank pay CBDC holders, whether retail or wholesale, interest? This decision has implications for the relative attractiveness for holding CBDC. In the retail context, it affects whether depositors prefer to hold savings in CBDC with the central bank or in traditional commercial bank deposits. This, in turn, affects the volume and stability of commercial bank deposits, their balance sheets and their lending activity. CBDC interest payments will compete with those from commercial banks, potentially pressuring commercial banks to raise their interest payments to depositors. For both retail and wholesale CBDC, implications for affecting monetary policy, whether deliberate or inadvertent, must be carefully studied and are the subject of much existing research.

- **Transaction anonymity**: Should CBDC transactions preserve customer privacy? Anonymity would encourage more consumers to use CBDC as a private and peer-to-peer alternative to cash. However, it increases the difficulty of reversing fraudulent transactions, catching illicit activity and recovering lost funds. Of note, if a central bank has strong motivations to employ CBDC for anti-money laundering, anti-corruption or tax evasion, or capital control and monitoring purposes, it will be less inclined to enable anonymity (at the cost of discouraging adoption). However, unless the central bank or state compels CBDC usage, those who wish to engage in illegal or illicit activity will continue to use cash and other alternatives (as well as new privacy-enabling cryptocurrencies) for these purposes.

- **Account and transaction volume limits**: Should central banks limit the amount of CBDC that can be held or transferred at one time? Such limitations can mitigate implementation and money-laundering risks. In the retail CBDC context, the central bank may limit the amount of CBDC a citizen can hold and transfer to reduce negative consequences. These include the potential for bank runs or lower demand for bank deposits if citizens see CBDC as a safer substitute for holding money thank commercial bank deposits. In the wholesale context, the central bank may limit whether commercial banks can employ CBDC for large-value payments.

For additional information on central bank experiments with CBDC and key issues, design choices and findings, see the International Monetary Fund 2018 report, "Casting Light on Central Bank Digital Currencies, the IBM and OMFIF 2018 paper, "Central bank digital currencies",and the BIS 2019 report, "Proceeding with caution – a survey on central bank digital currency".

Further, the BIS reports "Central bank digital currencies" (2018) and "Cryptocurrencies: Looking beyond the hype" (2018), and the US Federal Reserve Board's "Distributed ledger technology in payments, clearing, and settlement" (2016) provide detailed descriptions of CBDC and key issues, opportunities and risks.

Where is wholesale CBDC research focused today?

The leading cases for wholesale CBDC consist of increasing efficiency in cross-border interbank payments and in interbank securities trading and settlement.

While wholesale CBDC also addresses domestic interbank payments, most developed countries already possess efficient domestic payment systems. The central bank of Denmark, for instance, says in a 2017 report: "In a Danish context, it is unclear what central bank digital currency would be able to contribute what is not already covered by the current payment solutions" (page 1). For some emerging economies, domestic interbank payment systems are not yet highly efficient and CBDC could potentially improve these systems.

Most early-stage pilots have focused on wholesale CBDC for domestic use. As tests have often occurred in countries whose domestic interbank payment systems are already efficient, early research conclusions do not generally point to strong value from CBDC for this application alone. This is the case for the phase one trials of the Bank of Canada's Project Jasper, the South African Reserve Bank's Project Khokha, and the European Central Bank and Bank of Japan's joint Project Stella.

In later phases of these pilots, the central banks test the value of DLT when applied to expanded contexts and connected with other DLT-enabled processes. This includes cross-border interbank payments, interbank securities trading and settlement, or even trade finance where there is high potential to increase efficiency. In these contexts, CBDC may prove more beneficial.

In one of the most exciting areas of research, wholesale CBDC is tested for rapid and complete cross-border interbank securities transactions not possible today. In this scenario, otherwise known as a "delivery versus payment" transaction, the full and final payment and settlement for a trade occurs at the same time the asset is fully (or "atomically") delivered to the buyer. Both the asset and currency are located on the distributed ledger and they are traded simultaneously. The result is greater operational efficiency and reduced settlement and counter-party risk.

The ECB and Bank of Japan Project Stella (phase 2), the MAS Project Ubin (phase 2), the Deutsche Bundesbank BLOCKBASTER prototype (2016-2018), and the 2018 joint paper "Cross-border interbank payments and settlements" cited above by the Bank of Canada, Bank of England and MAS all investigate this specific application.

CBDC in macroeconomic models

To date, a reliable and thorough quantitative analysis of the effects of CBDC or other DLT-enabled applications has not been conducted and may constitute a barrier to adoption by policy-makers. In limited cases, macroeconomists have applied existing models to evaluate how a CBDC could impact GDP or welfare in a country. The results of these papers indicate mixed benefits and the authors recognize the limited ability of the models to estimate outcomes given the complexity of conditions.

A 2018 Bank of Canada staff working paper, entitled "*Central bank digital currency and monetary policy*", evaluates how a non-anonymous CBDC affects welfare and monetary policy when it is issued in environments where cash persists and where it does not. Where cash continues to be used, the analysis shows CBDC to have no notable effect or to decrease welfare (in GDP terms) depending on conditions. If cash is removed from the economy (an unlikely scenario in the short and medium term), the authors find that, within the model's conditions, CBDC could increase GDP permanently in Canada by up to 0.64% and in the United States by up to 1.6%, owing largely to an expanded monetary policy toolkit.

The most commonly stated rationale for an expanded monetary policy toolkit in a no-cash environment is that central banks would be able to effect a negative nominal interest rate policy. In this context, they could charge citizens on deposits. This policy would stimulate spending in recessionary and deflationary environments by discouraging household savings. This option is unavailable today in the presence of cash, as citizens would prefer to save in cash and other assets rather than have deposits "taxed" by a negative interest rate.

A strongly optimistic 2016 Bank of England staff working paper, entitled "*The macroeconomics of central bank issued digital currencies*", suggests that an interest-paying retail CBDC could permanently raise GDP by up to 3% in an economy depending on implementation. It also notes salient risks to financial and monetary stability associated with CBDC implementation.

Finally, a 2018 Federal Reserve of St. Louis working paper, "*Assessing the impact of central bank digital currency on private banks*", combines multiple existing economic models to evaluate the impact of CBDC issuance on a country's banking sector in an environment where banks have monopolistic power. The author finds that an interest-bearing CBDC increases financial inclusion and diminishes demand for cash, while decreasing bank profits. He finds that CBDC does not necessarily lure depositors away from commercial banks if the banks compensate for the heightened competition from the central bank by paying higher interest rates.

Alternative payment systems

In the future, some experts believe we may see forms of central bank digital currency facilitate alternative or bilateral international payments systems that operate outside current dominant systems. For instance, a blockchain-based state currency could operate outside the SWIFT messaging system that facilitates global payments. The result could potentially include a greater diversification in international payment processes and monetary systems away from the US dollar and other major currencies and away from a limited set of institutions. States and financial actors may, as a result, have greater independence and autonomy over payments they conduct in the international sphere.

CBDC and geopolitical manoeuvring

States may potentially use DLT-based digital currencies for geopolitical gain. As with the section above, little is written on this subject but the potential role that CBDC and DLT-based digital currencies may play in the future of monetary systems is worth noting.

Regional economic influence
Some experts believe that a state could use a state-backed digital currency outside traditional payment systems to compete with reserve currencies in a region. By doing so, it could potentially grow economic influence and power.

Jennifer Zhu Scott, a blockchain technology expert and venture capital investor, wrote the following in a 2018 blog post entitled, "Is China about to launch its own cryptocurrency?":

"*If the PBoC [People's Bank of China] issues its own cryptocurrency and uses it to replace the dollar for trade along the Belt and Road, it could challenge the dollar's dominance and offer optionality to these countries. A considerable portion of the Belt and Road trade and investments are being carried out by Chinese state-owned enterprises with a political mandate. This could make the implementation of a PBoC-backed cryptocurrency more efficient. Such a digitally controlled approach could allow China to strike a balance between capital control and RMB internationalization that wasn't possible before*."

Sanctions circumvention
In rare cases, a state may also seek to use CBDC to bypass or counter international regulations or sanctions, or to bolster an autocratic regime. Iran appears to be issuing a state-backed digital "crypto-rial" currency, with the primary motivation of bypassing international sanctions.

In response to Iran's actions, US lawmakers have introduced at least two bills explicitly aiming to curb the development of a state-backed digital rial. Bill S.3758, sponsored by Senate Republicans in December 2018, aims to "impose sanctions with respect to Iranian financial institutions and the development and use of Iranian digital currency…" The bill, currently under review, requests the US Secretary of the Treasury to report to Congress on Iran's efforts and its potential implications, alongside other measures. It further quotes the Civil Defense Organization of Iran as having stated that "cryptocurrencies can help bypass certain sanctions through untraceable banking operations."

Sovereign-state financing
As another example, Venezuela has allegedly issued the "petro" digital currency on the NEM blockchain platform in February 2018, in part to serve as a mechanism to attract government financing during rapidly deteriorating domestic economic conditions and a plummeting bolívar. It is supposedly backed by the state's oil and mineral reserves. The petro may also support sanctions circumvention.

Conclusion

Dozens of central banks from across the world are actively investigating whether blockchain and DLT can help solve long-standing interests such as banking and payments system efficiency, payments security and resilience, financial inclusion and more. Research began in 2014 with the Bank of England and now includes more than 60 research papers and multiple large-scale technology pilots exploring CBDC and other applications. In sum, central banks are investigating DLT for at least 10 distinct use cases.

Research and experience vary across countries, and many central bank researchers have yet to conclude whether DLT can provide value to their processes given salient risks and limitations. In rare cases such as with the Bank of France, a central bank has successfully deployed a DLT-based application. In other cases, central banks have concluded that blockchain technology does not provide valuable opportunities for their economies when considering the risks and downsides. In the least, many monitor developments by peer institutions and within the private cryptocurrency markets.

Emerging country central banks may experience the greatest gains from DLT implementations where existing financial processes and technology systems are not yet highly efficient or deeply rooted. They may also achieve greater financial inclusion from implementing CBDC or other blockchain-based applications. For central banks around the world, DLT applications such as CBDC can increase efficiency and reduce frictions in cross-border payments, on both the consumer (retail) and the interbank (wholesale) levels.

Over the next four years, we should expect to see many central banks decide whether they will use blockchain and distributed ledger technologies to improve their processes and economic welfare. Given the systemic importance of central bank processes, and the relative immaturity of blockchain technology, the banks must carefully consider all known and unknown risks to implementation.

Acknowledgments

I am grateful to Dirk Bullmann, Sumedha Deshmukh, Ousmène Jacques Mandeng, Jesse McWaters, Mauricio Ulate, Sheila Warren and Markus Zschocke for their very helpful feedback on this paper and ongoing guidance.

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