Institute
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An addendum to **"A Cashless Society- Benefits, Risks and Issues (Interim paper)"**

Understanding Central Bank Digital Currencies (CBDC)

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Table of Contents

Figures

Tables

Executive summary

The Institute and Faculty of Actuaries (IFoA) is the UK's chartered professional body dedicated to educating, developing and regulating actuaries based both in the UK and internationally. The Institute promotes and supports a wide range of research and knowledge exchange activities with members, external stakeholders and international research communities.

This paper has been written by a volunteer working party, sponsored by the Finance & Investment board at the IFoA, focused on the topic of a Cashless Society. The Working Party studied international developments related to new technologies that led to the introduction of new methods of payments.

The rise and volatility of cryptocurrencies have captured the interest of many commentators, particularly due to the excitement over a new technology, known as Blockchain, to resolve some economic development limitations and power decentralised payment systems. This paper provides a comprehensive overview of the topic of CBDCs for Finance and Investment professionals, including an overview of Central Bank thinking and the possible implications of introducing a CBDC.

A switch from public fiat towards private electronic money challenges the definition of money, the access to legal tender, the role of Central Banks, the financial intermediation model and the transmission of monetary policy. Central Banks have been under pressure to respond to the dramatic developments of cryptocurrencies and improve the efficiency of payment systems.

Central Banks have embarked on exploratory projects to study the potential for issuing Central Bank Digital Currencies. An array of models is under consideration, yet a clear proposal is elusive: the effects of a CBDC on interest rates, financial stability, and security require careful assessment. Changes to financial intermediation would have implications for bank funding and liquidity.

Technology innovation facilitated cryptocurrencies; Blockchain enables transactions without a central authority which presents advantages that have been hailed as the key to the future growth in international trade. However, performance, interoperability, scalability, and security concerns leave Central Banks unconvinced that the technology is mature enough to replace current systems.

The vast literature emanating from Central Bank projects throughout 2018 shows an array of views towards the entwined topics: they tend to provide a negative view on cryptocurrencies. However, the potential benefits of Blockchain technology for improving public functions are increasingly accepted with some countries seeking to attract investment in the area. Likewise, the potential benefit of a CBDC itself divides opinion in the international community, with a variety of positions.

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The Cashless Society Working Party: https://www.actuaries.org.uk/practice-areas/finance-and-investment/finance-and-investment-research-working-parties/cashless-society-working-party

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Central Bank Digital Currency; CBDC; Blockchain; Cryptocurrency; Crypto assets

Definition

As per the Bank for International Settlements [4], “CBDC is not a well-defined term. It is used to refer to a number of concepts. However, it is envisioned by most to be a new form of central bank money. That is, a central bank liability, denominated in an existing unit of account, which serves both as a medium of exchange and a store of value […] This mix of new and already existing forms of central bank money makes it challenging to precisely define what a CBDC is. In fact, for purposes of analysing what may change, it is easier to define a CBDC by highlighting what it is not: a CBDC is a digital form of central bank money that is different from balances in traditional reserve or settlement accounts.

For clarity, CBDCs should be viewed in the context of other types of money. Below is a taxonomy of money in the form of a Venn-diagram referred to as the money flower (Bech and Garratt (2017)). The version here focuses on the combinations of four key properties: issuer (central bank or other); form (digital or physical); accessibility (widely or restricted); and technology (token- or account-based). Money is typically based on one of two basic technologies: tokens of stored value or accounts (Green (2008) and Mersch (2017a)). Cash and many digital currencies are token-based, whereas balances in reserve accounts and most forms of commercial bank money are account-based.”

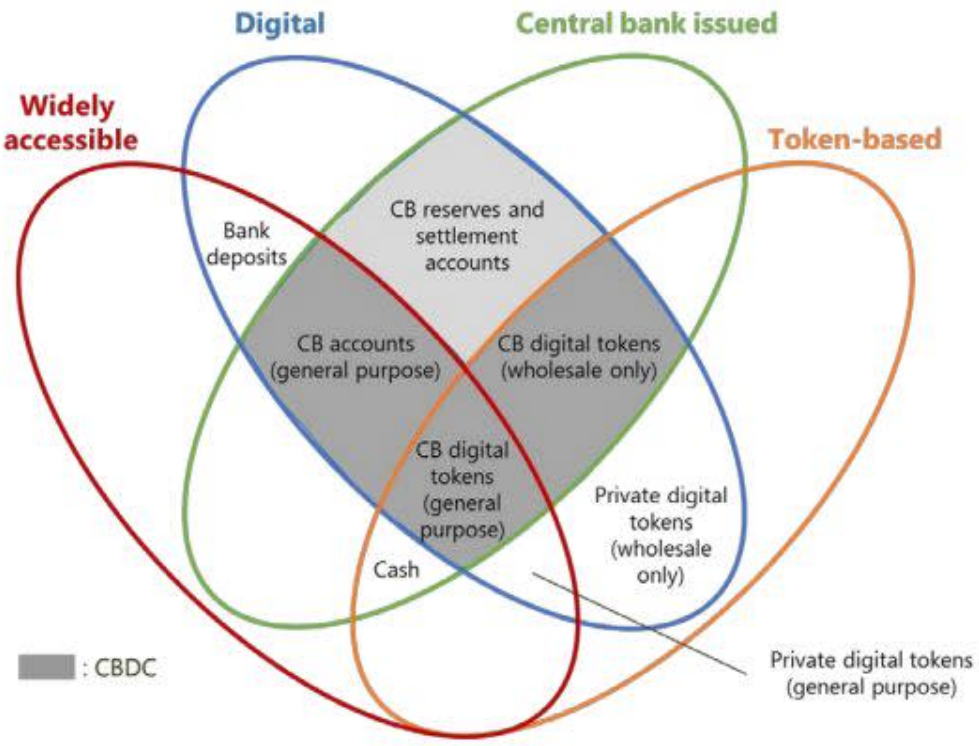


Figure 1: The Money Flower: A taxonomy of money. Bank for international Settlements [4]

Acronyms

AML: Anti Money Laundering

CB: Central Bank

CBDC: Central Bank Digital Currency

CFT: Counter Financing of Terrorism

ELB: Effective Lower Bound

ELB: Effective Lower Bound

FMI: Financial Market Infrastructure

ICO: Initial Coin Offering

KYC: Know Your Customer

NBFI: Non-Banking Financial Institutions

P2P: Peer-To-Peer

PBoC: People's Bank of China

POS: Point Of Sale

RTGS: Real Time Gross Settlement

Understanding Central Bank Digital Currencies

Section 1: Introduction

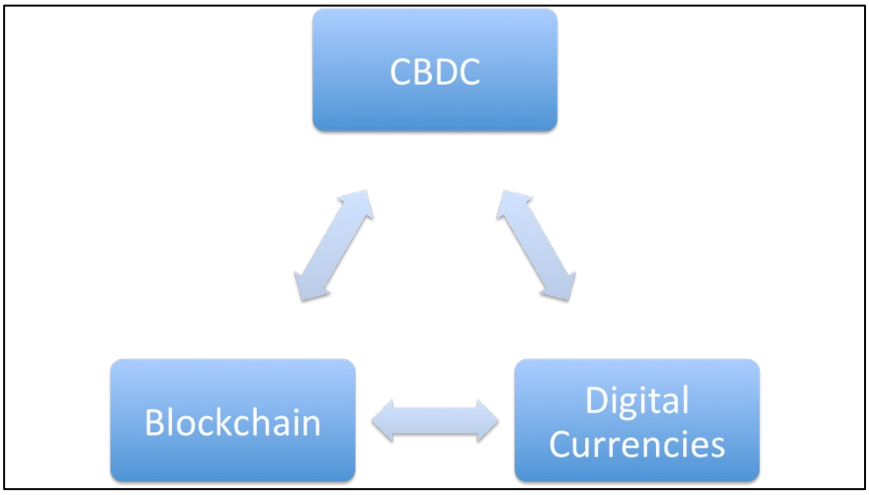
This paper provides a comprehensive overview to Finance and Investment readers about the topic of Central Bank Digital Currencies (CBDC). The recent international exploration into the future of Central Bank money is all the more complex as it is interconnected with two equally dynamic entities: digital currencies and Blockchain technology.

The interest towards CBDCs arises from developments that started with the 2008 financial crisis: the appearance of cryptocurrencies and the rise of digital transactions; the latter leading to the decreasing role of physical notes and cash.

The following section then provides a deep dive on the concepts of a CBDC, and the reasons why a Central Bank (CB) might wish to introduce a CBDC. It then explains the possible models, before focusing on the associated monetary and ecosystem challenges.

Cryptocurrency is a digital currency in which encryption techniques are used to regulate the generation of units of currency and verify the transfer of funds, operating independently of a Central Bank. The technology chapter introduces the core concepts of the technology that underpins cryptocurrencies and that is being explored for the future of payment systems. However substantial the proclaimed benefits may be, some performance limitations would weigh on the cost/benefit analysis.

As a result of all factors, CBs concluded differently towards the potential benefit of CBDCs for their countries. They also hold differing views towards cryptocurrencies and Blockchain technology. The last section provides an overview of the conclusions and decisions made in various countries.



Section 2: The context of Central Bank Digital Currencies

The Global Financial Crisis did much to change the financial landscape and inherently people's trust in the banking system. The rise of cryptocurrency may be as such an unsurprising development, beginning in 2009 when an individual or a group writing under the pseudonym Satoshi Nakamoto laid out its theoretical framework in "Bitcoin: A Peer-to-Peer Electronic Cash System." Cryptocurrency offers an alternative method of storing money and making payments without relying on the traditional banking system and government controls.

The initial issuance of Bitcoin has led to much interest in cryptocurrencies as seen in the rise in their value in the following years. The much regaled story of a programmer in May 2010 who purchased two large Papa John's pizzas for 10,000 bitcoins, worth about $30 at the time but whose future value rose to $82 million eight years later [20]. There is a constant flow of new cryptocurrencies offering improved solutions coming to market. There were 2,520 cryptocurrencies [2] available as of 4 February 2019 with a total market capitalisation of $113billion. This is astounding when we think that this commenced with just a single cryptocurrency in existence ten year previous (Bitcoin).

In their current form, cryptocurrencies are imperfect, but they may play a significant role in increasing global economic participation and protecting against government overreach. Globally, the World Bank estimates that there are 2 billion people without bank accounts of which a third of those are living in Sub-Saharan Africa. Given that cryptocurrencies have low adoption costs and are available online without the need to access a physical bank, cryptocurrencies offer a convenient and safe alternative. Many of the unbanked do not have clear identifying information, making it difficult to implement traditional banking Know Your Customer and Anti Money Laundering practices.

With a smartphone and internet connection, anyone can use cryptocurrencies to send and receive money and the transaction costs are often significantly lower than traditional solutions. The transfer is fast and secure and the barriers of entry are low. It also provides an alternative solution in countries facing hyperinflation.

Venezuela has transacted 17.1 billion [5][12] bolivars for bitcoin, in fiat terms, in the seven days ending 2 February 2019. This was the highest amount transacted on record for Venezuela. The country's currency, bolivar suffers from rampant hyperinflation and capital controls imposed by the government have placed restrictions on citizens' access to foreign currencies. This pattern has been mirrored in Argentina representing a profound case study of Bitcoin's potential positive impact for citizens faced with devaluation in their fiat currency. Bitcoin provides a store of value and a means for transferring money, even if this is later to be exchanged for an alternative fiat currency such as USD, enabling citizens to skirt oppressive government regimes. It is little surprise that there has been a rapid increase in the volume of exchanging the Bolivar and Peso for Bitcoin.

Cryptocurrencies are challenging the traditional pillars of the financial system and against this backdrop CBs are faced with the threat of individuals being able to store, spend and move value without reliance on the fiat currency. This is a huge threat to the traditional role that CBs play in monetary policy and so it is little surprise that there is gathering momentum across developed banks to analyse and understand the potential effects of introducing a CBDC.

2.1 What is money?

Money can be described as a generally accepted medium of exchange for goods and services [1]. Virtually anything can be considered money, as long as it performs the three major functions of money, namely as a medium of exchange, store of value and unit of account.

In the developed world there are two traditional forms of money, fiat money and commercial bank money. Fiat money, in the form of notes and coins, gets its value because the government declares fiat money to be legal tender, which requires all people and firms within the country to accept it as a means of settling debt. By definition, fiat money has an intrinsic value, which is significantly lower

than its face value. Its value is derived through supply and demand forces. This is the form of currency with which we are most familiar.

An additional form of money is commercial bank money which can be described as claims against financial institutions that can be used to purchase goods or services. It represents the portion of a currency that is made of debt generated by commercial banks. Commercial bank money is created through fractional reserve banking. Fractional reserve banking is a banking system in which banks only hold a fraction of the money their customers deposit as reserves. This allows them to use the rest of it to make loans and thereby essentially create new money. Commercial banks and other selected financial institutions hold these balances at the Central Bank (CB) to facilitate electronic settlement in Real Time Gross Settlement (RTGS) systems. This is a form of electronic CB money.

2.2 Transition towards a Cashless society

Could we be entering into a cashless society? [1][10] There is a complex range of factors driving the transition to a cashless or “less cash” society in countries around the world. Regional analysis exposes key differences in the drivers for a cashless society. In western countries, convenience appears to be the main force driving a natural evolution towards a cashless system, supported by lower transaction costs that make contactless payments more competitive than cash transactions. There seems to be little general political interest in removing cash altogether, other than for high denomination notes in the fight against money laundering, terrorism, tax evasion and corruption. The transition also appears to be happening by stealth, without active government intervention in satisfactory transition management.

Meanwhile, Africa has become a mobile payments innovation powerhouse, out of a necessity to equip the unbanked with access to a payment infrastructure. In Asia, India’s latest demonetisation exercise was aimed at restructuring the economy for a sustainable future, seeking to reduce corruption and improve tax collection. In China and elsewhere in Asia, the digital economy and associated investments in infrastructure and payment systems, designed with financial inclusion in mind, drive cashless transactions. Innovations in Africa and Asia are now being exported to the western world.

2.3 Economics of money

Physical cash emitted through national infrastructure is financed through public funds. De-cashing, defined as transferring to card and electronic payments has implications for:

- The equilibrium of the national money infrastructure, from the cash supply chain up to revenue from seigniorage[1].
- The sustainability of per-transaction cost transfer onto businesses and consumers, due to the proportional growth of commercial players in the payment ecosystem.
- The ability to sustain the drive towards financial inclusion.

Transaction costs for non-cash payments through private payment providers were a global concern in 2018, expressed by governments, Central Banks, the public and retailers [6], whereas the cost of cash was seldom discussed. In Africa, the priorities between tax collection and economic development required a fine balance. A number of Asian countries have placed the issue at the centre of their national payment strategies.

[1] Seigniorage is the profit made by a government by issuing currency, especially the difference between the face value of coins and their production costs.

2.4 Financial exclusion

A less-cash economy can either increase or decrease financial exclusion. There is a risk that de-cashing could increase financial exclusion if the interests of vulnerable groups such as the aged, disabled and poor are overlooked. For example, limited access to bank accounts or the internet more broadly forces parts of society to use cash, which increasingly prevents access to services and results in further economic exclusion. By contrast, in developing economies, technology can be an enabler for financial inclusion, for example the M-Pesa mobile payment system in Kenya [1].

2.5 Crypto currencies and assets

The dramatic rise in the value of cryptocurrencies in late 2017, followed by a series of corrections over 2018 has been given much public attention. These currencies offered transformative potential to simplify payments and operate independently of financial institutions. However, many view them as a speculative asset with no intrinsic value but from which material profits could be made. Unsurprisingly, as the number of investors grew over 2017 the value of the coins also rose, which further increased the volatility of the cryptocurrencies. Cryptocurrencies are complex payment systems in which users have no legal recourse.

Asset Type	Volatility
S&P 500	6.66%
Gold (LME)	10.19%
Crude Oil (Brent)	23.85%
Bitcoin	97.18%
Ether	136.68%

Source: Wind, Bitfinex, and the PBC staff calculation. The returns of Gold, Crude oil, Bitcoin and Ether in US D.

Table 1 Annualised daily return volatility of different assets in 2017 [21]

While there were 66 varieties of crypto-assets in 2013, the number quickly rose to 644 in 2016, 1,335 as of end-2017 and 2,116 in January 2019 [2]. The types and prices of crypto-assets and the number of relevant trading platforms have experienced a boom. Capitalisation of crypto-assets over the years has skyrocketed from around USD 10 billion at end-2013 and USD 16.1 billion at end-2016 to USD 572.9 billion at end-2017, accompanied by price bubbles and excessive volatility. As of April 2018, the number of trading platforms for crypto-assets had exceeded 10,000 [5][21].

The high volatility of these assets makes it difficult for the market to perceive these currencies as being a stable means of payment for future transactions. Yet Governments fear the rise of cryptocurrencies, leading to many CBs investigating the potential to introduce their own digital currency also known as a CBDC. The reason for investigating these measures is because governments control fiat currencies and in turn they use Central Banks to determine the monetary policy to exert economic influence. This control over currency is lost when non-government bodies create their own currencies, which may have implications on fiscal policy and for financial intermediation.

Section 3: Concepts of a Central Bank Digital Currency

Some Central Banks have started to analyse the potential to issue digital currencies of their own. This research has been driven by the success of new technology in the financial sector, the declining use of cash and the rise of digital currencies. Introducing a CBDC will have implications on the role of the CB and may have knock on impacts on financial intermediation. CBs already offer access to their digital account-based CB money to banks and a limited number of other institutions. In contrast cash is available to all but with the declining use of cash; access to the safety of CB money also declines. However, given the complex financial system any changes must be carefully considered.

3.1 What is a CBDC?

The Bank of England have described a CBDC as electronic CB money that:

(i) Can be accessed more broadly than reserves,
(ii) Potentially has much greater functionality for retail transactions than cash,
(iii) Has a separate operational structure to other forms of Central Bank money, allowing it to potentially serve a different core purpose, and
(iv) Can be interest bearing, under realistic assumptions paying a rate that would be different to the rate on reserves. [11]

3.2 Why issue a CBDC?

3.2.1 Ensure public access to legal tender if cash were phased out.

A CBDC would ensure that the public have access to legal tender if for some reason cash were no longer widely available. As legal tender this would mean that both cash and CBDC would be legally recognised as a form of payment and represent a claim on the CB / government [13].

Cash use is increasingly reducing due to the ease of payments using cards, apps and contactless. Although it is very unlikely that a CB would remove cash from the payments system, it may occur due to negative externalities of cash [19]. Cash by its nature is difficult to trace which makes it attractive for tax evasion, money laundering and illegal transactions. Cash also poses a greater security risk in transporting funds and in making payments as there is no record of exchange. It could be that future governments wish to remove cash to reduce crime and improve tax receipts. If both CBDC and bank notes were offered, overall seigniorage might increase due to a larger quantity of money in circulation. However, there can also be increased costs to a Central Bank when both options are provided. The overall effect of CBDC on seigniorage is unclear [22].

3.2.2 Improve efficiency of payment systems

A CBDC could improve the efficiency and safety of both retail and large-value payment systems. On the retail side, the focus is on how a digital currency can improve the efficiency of making payments—for example, at the point of sale (POS), online and peer-to-peer (P2P).

There could also be benefits of having a CBDC for wholesale and interbank payments; for example, it could facilitate faster settlement and extended settlement hours.

A CBDC could also support the removal of low value coins through delivery of electronic change. The Bank of Korea in April 2017 rolled out a coinless society trial, allowing customers to deposit their change onto prepaid cards instead of accepting small change from purchase. This also has cost saving benefits as the country spent 53.7 billion Won (£36.7m) on producing coins in 2016 alone.

3.2.3 Transition towards a less-cash society

In a cashless society, it would be envisaged that there would be no coins or notes available to individuals and that all money would be exchanged in a digital format. It is not envisaged that there will be a move to ban notes and coins but as the number of digital transactions increases and the withdrawal of cash from ATMs declines, it appears that the developed world is moving towards a less cash society.

It is likely that a government would try to regulate any cryptocurrency that may transform the payment system. In such an instance it may be found that a digital currency with Central Bank backing may be a credible alternative.

3.2.4 Competition from private e-money

The benefits of a widely accessible CBDC may be limited if Central Bank-issued fiat money is eclipsed by privately issued e-money. The commercial purposes of private e-money providers which aim to maximise their own profits does not align with a fiat currency. Governments issue social welfare using the fiat currency and should the privately issued e-money have a monopoly then there may be a social welfare cost. The State provides the payment of benefits using the fiat currency. If the privately issued e-money was more widely accepted and used than the fiat currency, then those receiving benefits would be at a disadvantage relative to the wider public.

3.2.5 Improve cross border payments efficiency

A joint study published by the Central Banks of Canada, the U.K. and Singapore [3] focused on the potential for a CBDC to improve counterparty credit risk for cross-border interbank payments and settlements. The wholesale version of CBDC limits its use to only financial institutions and markets.

The current model for cross-border payments relies upon CBs operating the RTGS infrastructure within which commercial interbank obligations must settle. There are limitations to this system as there are time lags for cross-jurisdictional payments, during which counterparties are exposed to credit and settlement risk from their correspondents.

The study [3] analyses the use of wholesale CBDCs as an alternative approach to cross border payments and found:

- A jurisdiction specific wholesale CBDC which cannot be exchanged across borders offers little benefit over the existing model;
- A jurisdiction specific wholesale CBDC which can be exchanged across borders could significantly improve counterparty credit and payment and settlement risks;
- A single universally accepted wholesale CBDC could also significantly improve counterparty credit and payment and settlement risks.

The benefits of these CBDCs include 24-hour availability, anonymity and eliminating counterparty credit risk for participants. However, all of the wholesale CBDCs were found to perform worse than the existing governance framework. The wholesale CBDCs would lead to a mix of benefits and drawbacks for Central Banks' future role and oversight. The study did not provide any analysis on cross border payments for a widely accessible CBDC.

3.3 CBDC models and designs

There are various design choices for a CBDC, from determining who should be granted access to the degree of anonymity and interest-bearing characteristics. The research is in an exploratory

phase in trying to understand the technological and economic impacts of introducing CBDC. However, attempting to understand the macroeconomic consequences of adopting a CBDC faces the problem that there is no historical experience to draw upon.

The value of government money is determined by its unique legal and political characteristics. Fiat currency can be submitted by any party as a means of final settlement of taxes, fees, fines, and privately–incurred liabilities. A CBDC should share the same underlying value as all other forms of government issued money and therefore have the full faith and credit of the issuing state.

For the Central Bank to serve as a central counterparty for all payments being processed using a CBDC, the CBDC should have the following features:

- The digital currency is available to the public without restriction and is recognised as a legal tender for the country.
- The digital currency could take different forms based on either existing payment infrastructure technology or new crypto technology. In this section, we will not focus on the form of technology used but on the economic impact of introducing a CBDC.
- The Central Bank directly guarantees the at-par convertibility of CBDC into cash and/or reserves.
- The Central Bank would not provide lending facilities for holders of the digital currency.
- The CB may choose to pay an interest rate on CBDC liabilities consistent with the interest rate structure of other government liabilities, and the Central Bank's broader monetary policy and financial stability objectives [8].

The availability of CBDC can be limited to a predefined group of users such as commercial banks and Non-Banking Financial Institutions (NBFI) or an economy wide system where access is extended to households and non-financial firms.

3.4 Monetary policy challenges to a CBDC

If fiat money usage were to fall significantly then the optimal policy of the Central Bank would depend upon the e-money issuer's policy, which could severely weaken the transmission of monetary policy and also restrict the ability of the Central Bank to act as the lender of last resort. Issuing Central Bank digital currency may prevent such competition if it is designed to be a perfect substitute of the privately issued e-money.

3.4.1 Effect on interest rates

CBDC holdings may strengthen the pass-through of the policy rate to money and lending markets. Its impact on monetary policy will be greatest if a CBDC is deemed an attractive asset. A CBDC would need to include the following design features; rules regulating its access by different types of agent, its availability beyond intraday use and whether it is interest-bearing, and at what rate.

If CBDC are interest-bearing and can be held without limits, this could affect holdings by institutional investors of other liquid, low-risk instruments (such as short-term government bills and repos backed by sovereign collateral). [4] The CBDC interest rate would help to establish a hard floor under money market rates. An interest-bearing CBDC could make monetary policy more effective as the pass through of interest rate changes by the CB would be more direct. If CBDC offers a direct alternative for deposits, banks would have less ability to independently set deposit interest rates.

The overall effects of CBDC on the (term) structure of interest rates are very hard to predict and will depend on many factors. To attract demand, short-term government paper and overnight repos with treasury collateral would likely need to provide some yield pickup compared to CBDC. This would lead to the short end of the sovereign yield curve being above the CBDC rate.

3.4.2 Reduce the effective lower bound

Following the financial crisis of 2008–09, several Central Banks set modestly negative policy interest rates to move aggregate demand toward potential output. It has been suggested, that the effective lower bound (ELB) on interest rates of zero has prevented the real interest rate from falling to the equilibrium negative level required to remedy the persistent shortfall in aggregate demand. This ELB exists because depositors can withdraw interest bearing assets and choose instead to hold cash thereby avoiding negative interest rates. Holding large amounts of cash does generate costs in terms of storing cash against security risks and the difficulty in making large payments. This cost, or negative yield, of holding cash generates the lower bound on (negative) interest rates.

It has been suggested that replacing physical bank notes with a CBDC would remove the ELB on policy interest rates, permitting the CB to implement negative policy interest rates if that were warranted by economic circumstances. Reducing the ELB can be achieved through increasing the cost or feasibility of storing cash as a method of avoiding negative interest rates. CBs could achieve this through eliminating bank notes which would lead to greater issues in terms of financial exclusion. The alternative is to remove large-denomination notes so as to increase the frictions related to holding and storing cash. The UK has to a great extent implemented this tactic by making the largest denomination note available to be £50.

Negative nominal rates introduce a number of legal, operational, and economic frictions which limit the potential stimulus to aggregate demand. Negative nominal rates may also adversely affect the profitability of financial institutions and thus make financial conditions less accommodative than they would be otherwise [1][16].

3.4.3 Helicopter money

Ben Bernanke who served two terms as Chair of the Federal Reserve, the Central Bank of the United States, from 2006 to 2014 suggested that helicopter money would be an alternative expansionary fiscal policy which would have an effect on the real economy. Milton Friedman coined the phrase "helicopter drop" of money, which provides a cash injection from the government into people’s bank accounts in the belief that this will bring about higher inflation. In a deflationary economy consumers and businesses are reluctant to spend as the price will be lower at a future date. It makes debt more onerous because it will have to paid back with money that will be more valuable the next day.

The assumption is that with CBDC the ability to make a payment to an individual’s account would be operationally simpler as all of the public would hold an account with the CB rather than the government having to make a cheque payment to all individuals.

CBs have the ability to buy and sell assets to try to maintain stable inflation and growth, but Government would have to make the decision to make a helicopter payment as this involves spending money with no repayment. A core principle of many of the developed nations is that Central Banks should remain independent from politics and not fund the government with money-printing. Printing money from thin air to fund government spending has led to many examples of hyperinflation such as Weimar Germany in the early 1920s, Zimbabwe and the current hyperinflation in Venezuela. Venezuela's annual inflation rate at the end of 2018 was 80,000% [18]

The difference in policy between helicopter money and quantitative easing is that the CB buys assets to stimulate the economy through printing money but the important distinction is that the government has a responsibility to repay this debt as it matures. The CB can then use the repayment to issue further bonds but that will depend on its assessment of whether or not it is time to withdraw money from the economy [9].

3.4.4 Financial stability

A CBDC provides a safer currency for transactions and deposits than those transacted with a bank which has commercial risk. Commercial banks are not fully backed by reserves as part of their role in providing lending and their market operations. These risks became notably higher during the Great Financial Crisis as people chose to withdraw cash from their commercial bank deposit accounts in favour of holding cash. A CBDC would offer an alternative lower risk option for risk adverse households. However, this does introduce concerns for the financial stability of commercial banks.

3.5 Disintermediation of banks

The transfer of deposits from commercial banks to CBDC would have implications for bank funding and liquidity, if this movement is not offset by other agents moving from CBDC to deposits. The impact of this would be a reduction in the aggregate size of the banking sector's balance sheet, which threatens the sustainability of current bank business models. [14]

However, CBs can design to limit this risk through determining its attractiveness relative to deposits, e.g. limiting the services available on CBDC accounts such as overdraft and loan facilities and by adjusting the interest rate earned on CBDC. There would need to be considerable thought into the design of CBDC and the level of responsibility that the CB wish to accept while allowing commercial banks to maintain their current functionality, including loan allocation.

Equally banks, like all businesses, when threatened with new market factors will compete for business through becoming more innovative and competitive. Banks are likely to offer an incremental spread above the (policy) rate on CBDC to reflect the marginal credit risk, which is necessary to implement the CB's monetary policy. To offset increased funding and other costs, banks would probably undertake cost-reduction exercises and raise lending rates and fees. The higher lending rates would most impact those customers with the lowest price elasticity of demand, namely small businesses and on credit cards [6].

A potential risk rising from the introduction of a CBDC is greater competition, which in turn lowers the profitability and reduces the financial stability of commercial banks, particularly in an economic downturn. Commercial banks would potentially compete with CBDC accounts by offering higher deposit rates and be impacted from reduced revenue from cross border transactions. This is on the assumption that the CB can conduct cross border transactions more efficiently than traditional banks. However lower profitability may lead banks to investing in more risky assets in a search for yield.

Commercial banks would likely increase their reliance on overseas wholesale funding, adding greater risk by exposing the banking sector to economic downturns in other markets. The impact in a differing country would flow through to the domestic country via increased bank funding costs or reduced availability of funding [19].

3.6 Bank runs to CBDC

An oft-cited risk to introducing CBDC is the risk of a bank run as depositors would easily be able to transfer bank deposits to the CB. Under a stress scenario, CBDC would represent a risk-free option which would be available faster and with less friction than redeeming money as cash sums. The contraction in bank funding and the withdrawal of liquidity (in the form of CBDC) may put the CB in

the position of having to replace the funding that commercial banks had lost [14] This would have impacts on the financial system and possibly the wider economy.

A credible threat of a bank run may, under financial stress, constrain risk-taking and motivate banks to hold a larger capital margin to protect from market shocks. This could result in lower returns for commercial banks. [6] There are however steps that could be taken by policy makers to limit potential bank runs through adding a notice period for large CBDC withdrawals, limiting the balances available for CBDC for each type of depositor or imposing fees on large balances of CBDC, or removing the requirement for banks to convert deposits to CBDC.[2]

The Central Bank has a responsibility to maintain the public's confidence in bank deposits. Enabling the exchange of commercial bank money for Central Bank money on demand is fundamental in the design of CBDC. A challenge for a CB would be to enable a secure and stable means of storing money and limiting the risk of destabilising commercial banks.

3.7 Security and privacy

Issuing a CBDC may require, depending on the laws in each jurisdiction, additional monitoring and compliance under Anti-Money Laundering and Countering Financing of Terrorism (AML/CFT) laws. The CB might be required to monitor the users of the CBDC to comply with this legislation.

A CBDC may enable monitoring of transactions to prevent fraud due its centralised design, unlike cash. This visibility may deter certain users from choosing to make payments using CBDC as many may be uncomfortable with payments being monitored by a single source. The level of anonymity given in a CBDC will depend on the technology and chosen design features and this may differ from one country to the next.

If a CBDC is designed so as to allow for anonymous electronic transactions this would alleviate people's concerns about the safety of Internet transactions, making it similar to cash. This would improve the system's efficiency and increase adoption. At the same time, such anonymity would make it easier for users to avoid AML regulations, which may lead to an increase in illegal transactions or tax evasion. These negative externalities would bring additional social costs [7].

[2]Such a proposal is presented in Kumhof and Noone (2018).[11]

Section 4: Technology

One of the reasons for new technology to trigger intense study from Central Banks is that, according to the Bank for International Settlements [32], many Central Bank-operated wholesale payment systems are at the end of their technological life cycles, with obsolete and inefficient architectures.

In addition, cross border payments are cumbersome, error-prone, opaque, time consuming and costly: US$25 to US$60, i.e. at least 10 times the cost of domestic transactions, a barrier to growth in global trade [47][58].

A new paradigm appeared through Blockchain: "… *for the first time, a way for one Internet user to transfer a unique piece of digital property to another Internet user, such that the transfer is guaranteed to be safe and secure, everyone knows that the transfer has taken place, and nobody can challenge the legitimacy of the transfer. The consequences of this breakthrough are hard to overstate*." - Marc Andreessen, American entrepreneur.

4.1 Distributed Ledger Technology

A distributed ledger (also called a shared ledger or distributed ledger technology or DLT) is a consensus of replicated, shared, and synchronised digital data geographically spread across multiple sites, countries, or institutions. The distributed ledger database is spread across several nodes (devices) on a peer-to-peer network, where each replicates and saves an identical copy of the ledger and updates itself independently.

The primary advantage is the lack of central authority. When a ledger update happens, each node constructs the new transaction, and then the nodes vote by consensus algorithm on which copy is correct. Once a consensus has been determined, all the other nodes update themselves with the new, correct copy of the ledger. Security is accomplished through cryptographic keys and signatures.

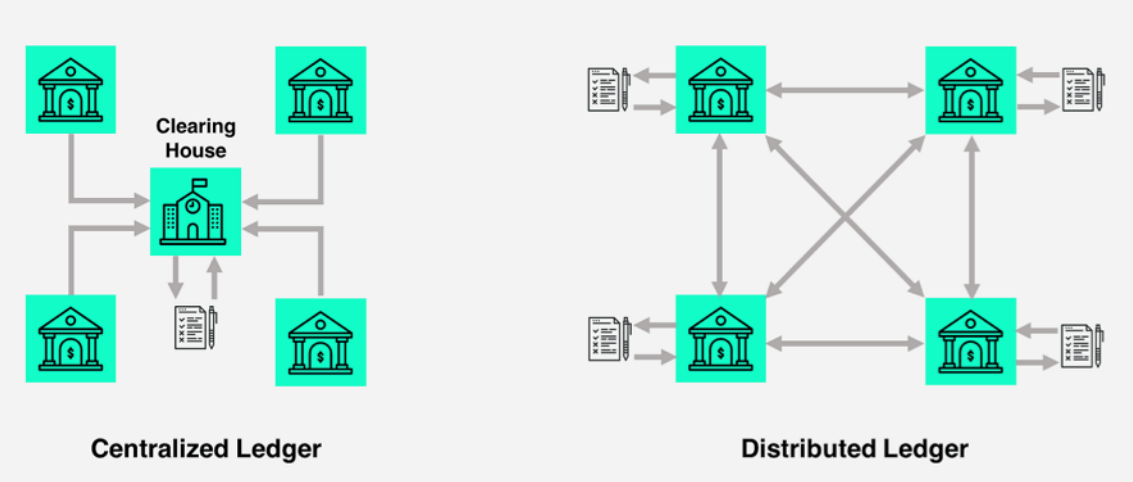


Figure 2- The difference between a centralised and decentralised ledger- Tradeix

A peer-to-peer network is required as well as consensus algorithms to ensure replication across nodes is undertaken. One form of distributed ledger design is the Blockchain system.

4.2 What is Blockchain?

Blockchain enables multiple users to make entries into a record of information and a community of users can control how the record of information is amended and updated. As such, every node in the network receives the same information and each node updates the record independently. This thereby eliminates the need for a trusted party to facilitate digital relationships.

It is on Blockchain technology that digital currencies have evolved. The most prominent example of a digital currency is Bitcoin. Bitcoin and other digital currencies are made available to the public through a process called mining, which is done using Blockchain technology.

Cryptography is used to validate transactions and prevent fraud. Records are kept through Blockchain technology. The use of encryption gives digital currencies a similar level of privacy as bank notes.

4.3 Blockchain terminology

The key concepts are tokens and smart contracts. A token is a state variable defined in the Blockchain. The number of tokens is unchanged during the transfer process, only the status is updated. As a result, there is no “settlement in-transit funds” or settlement risk.

The smart contract stipulates series of logic as per the algorithm (consensus), including issuance rules, transfer rules, destruction rules. The token contract manages a series of status.

4.4 Types of Blockchain

- Private: a single centralised entity has complete control over what is written on the ledger. There is only one writer.
- Permissioned: The write privilege is granted to a consortium of entities. They control the policies and are the only ones to propagate and verify transactions. The read privilege can be public or kept private.
- Public (also called permissionless): read and write are unrestricted. Identity management in the context of anonymous agents is through the “proof of work”, commonly known as the mining process.

4.5 Prerequisite for implementation

All participants in the Blockchain must have a digital identity, i.e. information to authenticate them, a sensitive political consideration for retail access to a CBDC.

4.6 Potential benefits to trade

Blockchain is predicted to raise international trade to new levels within 10-15 years, through a number of proclaimed benefits:

- Reduce cost of trading.
- Improve the efficiency of cross-border payments and the ability to resolve stuck transactions.
- Improve speed, efficiency and transparency in debt markets.
- Give small firms access to the global market.
- Improve transparency and security of all transactions.
- Simplify process for letters of credit (maybe bypassing these altogether) and trade finance.
- Improve monitoring and regulation of markets.

- Secure and share data and records, such as transaction history.
- Strengthen Intellectual Property rights.
- Improve governance and social outcomes in developing regions.

4.7 Limitations of Blockchain technology

4.7.1 Slow transactions

Physical performance affecting public Blockchains is a major limitation and barrier to adoption, as this comparative chart illustrates.

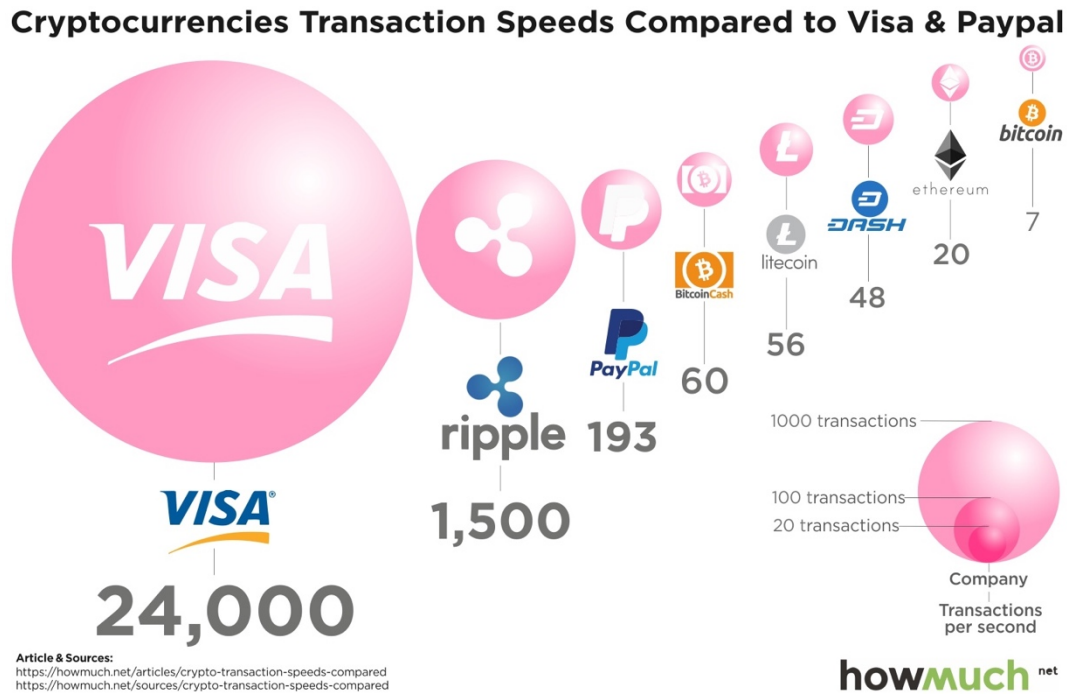


Figure 3- Cryptocurrencies transaction speeds compared to Visa and Paypal [74]

4.7.2: Consensus time delay

The mining process ("Proof of Work") requires vast amounts of computing power to record transactions and because all payments require miner approval there is a limit on the number of transactions that can be processed at any time. Once a transaction has been completed, it is irreversible. Miners are critical to ensuring the validity of each transaction and are rewarded by receiving newly created digital currency units. The alternative "Proof of Stake" attributes mining power to the proportion of tokens held by the miner and may help improve performance in the future.

4.7.3: Scalability

Most digital currencies have a source code that outlines the precise number of units that can and will ever exist and so there is a finite supply. Over time, it becomes more difficult for miners to produce digital currency units, until the upper limit is reached. Digital currencies finite supply makes them inherently deflationary, more akin to gold and other precious metals than fiat currencies. This too places a pressure on the price of digital currencies, unlike fiat currencies for which Central Banks can, in theory, produce an unlimited supply.

4.7.4: Design

It has been suggested that many issues with the performance of public Blockchain stems from excessive decentralisation, leading to inefficiency. Further research and development activity will likely resolve the trade-off between decentralisation and performance.

4.7.5: Link into the real economy

The environment within Blockchain cannot be extrapolated outside of Blockchain, for instance to translate “proof of ownership” into “proof of possession” (e.g. of a house). Blockchain must solve the real-life trust problem and needs to interface with trusted central mechanism outside of Blockchain.

4.7.6: Interoperability:

Current uncoordinated research and development activity leads to interoperability concerns between platforms due to different code languages, standards and applicable regulatory systems: to what extent can Blockchain platforms be used in an integrated manner?

4.7.7: Security:

Blockchain is trusted for being a highly secure, impenetrable technology as all users share the same information that has been verified by the miner. The security of a Blockchain is guaranteed through the use of cryptographic functions that are deemed to be relatively secure because breaking them requires huge computing resources, which are not generally available. However, it has been suggested that they are not completely immune from advances in technology, namely the rise of quantum computing. Unlike ordinary computers that operate on a binary system accepting bites of the form 0 or 1, a quantum computer works with particles that can be in superposition. Rather than representing bits of value 0 or 1, quantum computers would have particles represented by qubits, which can take on the value 0, or 1, or both simultaneously. Quantum computing may have the potential to break the cryptography that conventional Blockchain relies upon as they are much more powerful. However, such an issue may be solved using next generation technology by using quantum cryptography in Blockchain and so the entire Blockchain may be a quantum phenomenon.

4.7.8: Vulnerability

All Blockchain systems have to address the inherent problems of double-spend, and issues such as blocks that have detached from the chain, accidentally or through attacks. As Blockchains are implemented in software, any number of software vulnerabilities can also exist due to poor code implementations.

4.8 Investment in Blockchain

The commercial war on Blockchain technology is rife between China and the USA [25], with Alibaba, IBM and Mastercard filing the most patents for developing new uses for Blockchain related technologies, with 80-90 patents each. Bank of America and the People’s Bank of China (PBoC) take 4th and 5th place with 53 and 44 applications respectively. The next group of contenders, with approx. Twenty filings each, includes Tencent Holdings, Accenture PLC, Intel Corp, Visa Inc, Alphabet Inc’s Google, Ping An Insurance, Bitmain, Sony and China State grid corporation.

4.9 The art of the possible

The potential for the Blockchain technology to enable CBDCs remains in the realm of “the art of the possible”. Blockchain may seem attractive due to the extensive automation potential to resolve inefficiencies in current systems. Yet, why would a CBDC need to be decentralised through a distributed ledger?

Section 5- International positions towards crypto assets, Blockchain and CBDCs

This section provides an overview of international positions towards the three interlinked topics. Any country may feature in several categories, as they may hold a negative view towards private cryptocurrencies, a positive one towards Blockchain technology, have no intention of launching a public facing CBDC, yet investigate the potential to upgrade Financial Market Infrastructure (FMI).

5.1 Regulatory attitudes towards private cryptocurrencies

Crypto-currencies generate a generally negative sentiment amongst Central Banks, with the following key arguments:

- Many countries deny them the definition of currency and point out that they do not meet the functions of money.
- They are a speculative, highly volatile, medium that distorts the market, pulling away investment from the real economy and innovation into bubbles.
- They are vulnerable to crime and expose consumers and investors to high risks of loss.
- Despite the decentralisation claims of the underlying technology, intermediaries still exist: miners, to maintain a ledger.
- The technology is not scalable, is inefficient, and has a high environmental impact due to miners' energy use for computing power.

The European Central Bank qualified them as "the evil spawn of the financial crisis", and a study identified large hypothetical scope for anticompetitive behaviours. The following table summarises public policy responses, as of January 2019.

Central Bank attitudes towards crypto currencies/ assets (Jan 2019) (References)	
Generally negative view	Azerbaijan, Australia, Bank for International Settlements, Canada, China, European Central Bank, Finland, France, Hong Kong, India, Indonesia, Japan, Malaysia, Netherlands, New Zealand, Norway, Russia, South Africa, South Korea, Switzerland, United Kingdom, USA.
Policy: Ban	China, India, Indonesia, Morocco, South Korea, Thailand.
Policy: Monitor	• No real risk to financial stability: Australia, India, United Kingdom, USA. • Ready if action required: Brazil, Malaysia, Russia, Singapore, Switzerland, United Kingdom. • Issued investor warnings: Canada, China, France (Bitcoin), ECB, Germany, Hong Kong, United Kingdom.
Policy: Regulate	• Integrate into existing financial regulatory framework: Canada, Hong Kong, Indonesia, Japan, Mauritius, Singapore, USA. • New regulatory framework: France (ICOs), Gibraltar, Japan, Mauritius, Thailand. • Consulting on regulations: Israel, Russia, South Africa.
Policy: Support	Brazil, Japan, Malta, Sweden, Venezuela, Bermuda, Germany, Israel, Switzerland, Ukraine.

Table 2 Central Bank attitudes towards crypto currencies/ assets [Ref]

5.2 Attitudes towards Blockchain technology

The Blockchain technology is generally accepted as offering substantial potential for improving public service functions, in particular to improve the cost and complexity of burdensome processes, whether financial or not. This leads several countries to position themselves as Blockchain friendly countries, to attract investment.

Cross border payments, electronic collaterals and security settlements are a good use case for implementation using blockchain technology. However, many countries have concluded the technology is yet too immature to risk implementation for critical large-scale payment systems. Performance does not seem to match or exceed that of settlement systems of the most developed countries, yet would inject unknown risks at this time, such as:

- Sustainability of the Blockchain industry.
- Excessive decentralisation viewed as the source of its performance shortcomings.

There is scepticism about the current potential of Blockchain technology for economic applications. Some have even raised concerns about a bubble situation in Blockchain investment and finance, with speculation, market manipulation and suggested conduct in breach of law and regulation is widespread. The following table summarises positions, as of January 2019.

Central Bank attitudes towards Blockchain (Jan 2019) (References)	
Recognise potential public utility	Canada, Bahamas, Eastern Caribbean, Russia, Turkey, Kenya.
Technology limitations are barrier to adoption	Canada, China, ECB, Germany, Netherlands, Hong Kong, Japan, Norway, South Africa, South Korea, USA.
Blockchain friendly countries	France, Hong Kong, Kazakhstan, New Zealand, South Korea.

Table 3 Central Bank attitudes towards Distributed Ledger Technology (Blockchain) [Ref]

5.3 Positions towards Central Bank Digital Currencies (CBDC)

Vast literature published in 2018 reflects the intensive global effort to assess the feasibility of CBDCs, given the breadth of models and applications. The lack of standardised definition and specification of a CBDC seems to reflect the early stage of exploration for opportunities and assessment of risks. Studies tended to unveil more risks than were hypothesized at their inception, spanning from technical, legal, economic, security, operational, to monetary policy. Current systems appear more effective than Blockchain at this stage of maturity.

The following table summarises public policy responses, as of January 2019.

Central Bank positions towards Central Bank Digital Currencies (CBDC) (Jan 2019) (References)	
Recognise potential value of CBDCs	• Maintain public access to Central Bank liability in event of declining use of cash: Norway, Sweden. • Facilitate de-cashing: Curaçao and Sint Maarten, Israel. • Improve cross border transaction systems: Canada, Hong Kong, Saudi Arabia, Singapore, United Kingdom. • Modernise interbank settlement systems: BIS, Singapore, Thailand. • Address underserved markets: Bahamas.
Have decided against planning to implement CBDC	Azerbaijan, Australia, Denmark, ECB, Estonia, Germany, Hong Kong, India, Israel, Japan, New Zealand, Norway, South Korea, Switzerland, USA.
Continue studies for long term potential	Brazil, Canada, China, Indonesia, Israel, Norway, Singapore, UAE, United Kingdom, USA, ECB and Japan (FMI).
Are actively developing experiments, trials	Bahamas, Eastern Caribbean, Kazakhstan, Philippines, Russia, South Africa, Sweden, Thailand, Ukraine, UAE, Uruguay.
CBDC operational	Iran, Marshall Islands, Senegal, Tunisia, Venezuela.
CBDC decommissioned	Ecuador

Table 4 Central Bank attitudes towards Central Bank Digital Currencies (CBDCs) [Ref]

Section 6: Conclusion

Globally, the means through which payments are made has changed drastically in the last ten years. In Africa, the unbanked have been enabled to make payments using their mobile phones. In Asia there has been a move to reduce the amount of cash payments, through reducing large denomination notes in India to removing coins in South Korea. In Europe and the US, the use of cash has reduced through online transactions and the increasing use of card payments. In South America, both Argentina and Venezuela have made use of Bitcoin to make monetary transfers and as a store of value as an alternative to the hyperinflation of their fiat currency.

With a changing payments landscape, Central Banks have recognised that they too need to develop to aid this transition and incorporate new technology. If a private e-money issuer was to control the majority of payments in a country and there was a clear move away from the fiat currency, the CB would lose its ability to implement monetary policy. Against this backdrop, Central Banks are trying to understand the financial and economic impact of introducing their own digital currency.

Introducing CBDC would have a seismic effect on the banking system. A wholesale CBDC provides citizens with an alternative and safer means of storing money, thereby reducing the deposits held with commercial banks. The greater competition for deposits may lead to higher deposit rates for depositors at the commercial bank and new innovation to encourage saving and borrowing. In contrast, there may also be greater risks for the commercial banks such as the risk of a run on the bank or the need to generate profits through investing in higher yielding, more risky assets.

The impacts of a CBDC will be influenced by the availability and design of the CBDC, the form of which is open to many different options. The CBDC implementation will also be impacted by the regulatory regime introduced by the CB to support commercial banks. At this stage many countries are in an exploratory stage but the risk of introducing a CBDC to the detriment of a well-functioning banking system will be taken with much thought and care. Each CB will need to consider the impact that they wish a CBDC to have; on monetary policy which will be determined by whether or not the CBDC bears interest, the personal and commercial implications and the viability of implementation using existing technology. Launching a CBDC entails large risks as potential economic disruption could outweigh the desired, but mostly untested benefits. However, what is right for some developed economies may not be true for developing ones, where risks and benefits are inherently different.

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