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Central Bank Digital Currencies and payments: A review of domestic and international implications

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CENTRAL BANK DIGITAL CURRENCIES AND PAYMENTS: A REVIEW OF DOMESTIC AND INTERNATIONAL IMPLICATIONS

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ABSTRACT / RESUME

Central Bank Digital Currencies and payments: a review of domestic and international implications

Recent technological developments linked to secure messaging and traceability present an opportunity to address certain challenges in international and domestic payment systems. From an international perspective, foreign exchange markets remain costly and relatively less efficient than domestic payment systems. From a domestic perspective, the decline in the relative importance of cash in most economies reflects changes in consumers' preferences, which questions the future of money and payment infrastructure. Against that background, private initiatives falling outside of current regulation, such as stable coins and other virtual assets, are associated with several risks and opportunities and have fueled the debate on the opportunities for central banks to issue new form of digital public currency. This note reviews those different propositions and examine their implication for the international and domestic payment systems.

JEL classification codes: E42, F33, G28

Keywords: CBDC, payment systems, digital currency, international markets, central banking.

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Monnaies numériques des banques centrales et systèmes de paiement: revue des implications locales et internationales

Les récents développements technologiques liés à la messagerie sécurisée et à la traçabilité de l'information offrent l'opportunité de relever certains défis des systèmes de paiement internationaux et nationaux. D'un point de vue international, les marchés des changes restent coûteux et relativement moins efficaces que les systèmes de paiement nationaux. D'un point de vue national, le déclin de l'importance relative des espèces dans de nombreuses économies reflète une évolution des préférences des consommateurs. Cela remet en question l'avenir de la monnaie et des infrastructures de paiement, tout du moins dans leur forme physique. Dans ce contexte, les initiatives privées échappant à la réglementation actuelle, telles que les stablecoins et d'autres actifs virtuels, sont associées à plusieurs risques et ont alimenté le débat sur les possibilités pour les banques centrales d'émettre une nouvelle forme de monnaie publique numérique. La présente note passe en revue ces différentes propositions et examine leurs implications pour les systèmes de paiement internationaux et nationaux.

Classification JEL: E42, F33, G28

Mots clés : MDBC, systèmes de paiement, monnaie numérique, marchés de change, banque centrale

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Central Bank Digital Currencies and payments: a review of domestic and international implications

By Lilas Demmou and Quentin Sagot[1]

1. Introduction

1. The development of financial market infrastructure is inherently linked to technological innovation and has revolved in the second part of the 20th century in response to an increasing integration of actors across borders at an ever-lower cost. Electronic money gained momentum from the 1970s' allowing vast amounts of money to be transferred first between financial institutions and then to a larger set of actors. Those developments have played a key role in supporting trade and economic activity. Yet in the face of recent technological advances, the existing settlement system is considered slow and costly and the demand for new kinds of medium of exchange, notably for digital currencies or tokens has increased, reflecting the emergence of new needs. The growing digitalisation of retail trade has fuelled this demand even further. While recent private and public initiatives aim at responding to those new needs, new challenges emerge for policy makers.

2. This paper takes stock of these developments and put forward some economic implications on payment markets for policymakers and analysts. First, ten years on from the worldwide emergence of a new type of privately-owned and decentralized digital financial assets, of which Bitcoin was the first and the current most well-known example, their potential economic impact is hugely debated. In 2019, the total market capitalization of cryptocurrencies amounted to USD 287 billion, from USD 18 billion in January 2017 (a circa 1500% increase, with a peak in January 2018 at USD 830 billion). Yet, this market remains small compared to the volume of assets exchanged on global financial market, especially regarding the market for currencies, to which these crypto-assets are often associated. Crypto-assets characteristics indeed make them a weak substitute to fiat currencies. In particular, their large volatility and cost of production inherently limit their use as a medium of exchange and reserve of value (FSB, 2018[1]). Further,

[1] Corresponding authors: Lilas Demmou (Lilas.Demmou@oecd.org), from the OECD Economics department and Quentin Sagot (Quentin.Sagot@oecd.org) from the OECD Centre for Tax Policy and Administration. The authors would like to thank for helpful comments, valuable discussions and insightful suggestions Laurence Boone, Luiz De Mello, Alain de Serres, Dennis Dlugosch, Guido Franco, Filippo Gori, Giuseppe Nicoletti (all from the OECD Economics Department), Caroline Malcom, Robert Patalano, Sebastien Schich, Ania Thiemann (all from the OECD Directorate for Financial and Enterprise Affairs) and Benoit Coeuré (from the Bank of International Settlements). Sarah Michelson, from the OECD Economics Department, provided excellent editorial support. This note has been prepared in the context of the OECD Global Blockchain Policy Forum organised by the OECD Blockchain Policy Centre.

the technology underlying these assets may not be flexible enough to ensure an adjustment of money supply to economic conditions, making them a weak instrument for monetary policy.

3. However, further innovations in the crypto-economic world present the potential to change this global picture, in particular the development of stablecoins, i.e. crypto-assets featuring a stabilization mechanism allowing them to anchor their price to a basket of stable fiat currencies or assets. While rather small in terms of market capitalization (circa USD 25 billion[2]), scaling projects, notably Facebook's Diem have the potential to disrupt the current monetary system based on national fiat currencies and pose several economic risks. First, regulatory settings on crypto-assets and stablecoins, established as speculation instruments may not abide by Payment Service Providers (PSP) standards and thus may not guarantee users similar operational security and system resilience. In particular, private actors present higher credit risk (or probability of default) than central agents ((Sveriges Riksbank, 2018[2])) and even if solvent, private entities face an inherent liquidity risk associated with their business cycles. Competition issues add to the problem as Tech giants could leverage their dominant position on international commerce by concentrating the operations of the market place on their own platforms, from advertising, to payments and potentially lending (OECD, 2020[3]). Additionally, the more concentrated is a payment market, the greater the risk of contagion in the system. These risks have fuelled the public debate on the necessity to regulate private currencies[3] (an issue not discussed in the present paper, but which notably affected the launch of Facebook's Libra initiative) and on the opportunities for central banks to issue new form of digital public currencies (CBDC).4 In 2019, 80% of world central banks, surveyed by the BIS, have declared pursuing work in the area of CBDC, though only a few engaged in the active development of pilots (Rice, van Peter and Boar, 2020[4]). Against this background, this note takes an exploratory perspective to examine the potential impacts of different CBDC designs on three areas: i) cross-border and domestic payment systems, ii) the role of the banking system; iii) the efficiency of monetary policy toolkits. Country-specific experiences are also reported given that the motivations for expanding CBDC may vary across countries, as do pilots' implementation level.

4. The paper is organised as follows. The next section provides a brief overview of the existing challenges with respect to the efficiency of cross-borders payment systems and examines the role that a CBDC could play to address them. Section 3 focuses on domestic payment infrastructures and analyses the disruptive effects that CBDCs could have on the financial sector and on the way central banks conduct monetary policy.

[2] Figures extracted from the website: https://stablecoinindex.com/marketcap on 01/12/2020

[3] To this date, after the initial development of virtual assets outside of established regulatory framework, the G7 and the G20 have called upon a coordinated research and collective regulatory effort on these issues and their links with payments. The G7 has mandated the Financial Stability Board (FSB) to frame regulatory aspects of stablecoins. The G20 has mandated the BIS Committee on Payments and Market Infrastructure (CPMI) to investigate/identify policy option to address weaknesses in cross-border payments, considering CBDC, among other options. The Financial Action Task Force focuses on regulating virtual asset service providers, in light of the standards of financial regulation regarding anti-money laundering and combatting The financing of terrorism (Anti-Money Laundering /Combatting the Financing of Terrorism – AML/CFT).

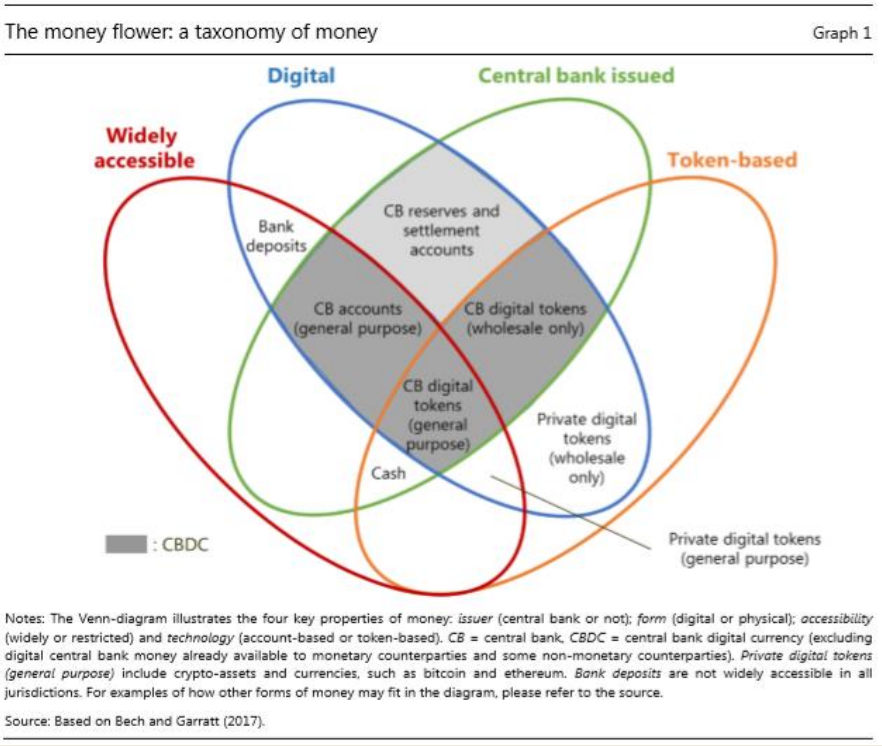
[4] Note that digital central bank money already exits under the form of commercial bank reserves deposited at the central bank.

Box 1. Attributes of a CBDC

Digital central bank money already exits under the form of commercial bank reserves, deposited at the central bank. The BIS "Money Flower" (Bech & Garrat, 2017[5]) has summarized potential directions for the issuance of a CBDC by distinguishing the forms of money according to four characteristics:

- A CBDC would inherently be digital, thus reducing some current inefficiencies associated with cash, notably by decreasing the cost of operating the cash infrastructure, even though current technologies used for crypto-assets may not be yet mature enough to be used in general purpose scenarios (see Annex A)
- A CBDC could be token-based or account based. Token-based currencies are similar to cash in that they do not depend on a central agency and rely on wallet technologies (e.g. Distributed Ledger Technology - DLT), allowing for peer-to-peer transactions (independent from central validation). Account-based currencies can otherwise be held within an account, either within a public or within a private financial institution, which are in charge of settling payments upon request.
- A CBDC can be designed for the general purpose and accessible to everyone or restricted for the use of a limited number of actors. This latter modality of money is at the core of our current two-tier system for monetary policy, where individuals settle their accounts in commercial bank's books, which themselves settle theirs on the central bank's books, in central bank money.
- Finally, the issuer of the currency can vary, as it can be public – via the central bank – or private as it is notably the case for crypto-assets.

Figure 1. The BIS Money Flower

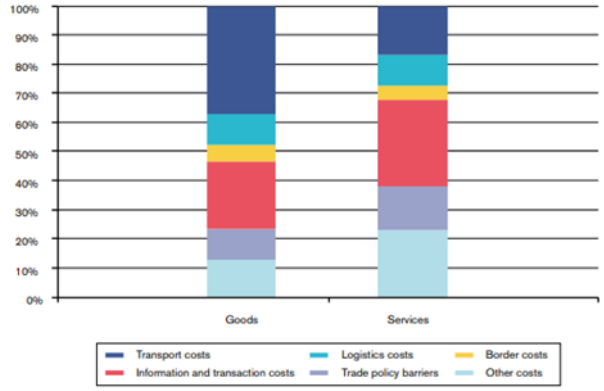


2. The opportunity of CBDCs to address international payment system challenges

2.1. Brief overview of international payments: a costly and slow payment system which may act as a barrier to trade and growth

5. An efficient cross-border payment infrastructure, enabling fast and affordable payments, is paramount to support international trade. Indeed, transaction costs appear to be the most important costs component in international trade for services, and the second one after transportation in trade for goods (WTO, 2018[4], Figure 2). The recent worldwide surge in e-commerce, fostering business-to-person sales as well as the significant increase in the volume of remittances exacerbate further the need for cost-efficient cross-border transactions. Against that background, the current cross-border payment system is deemed to be slow, costly and opaque, compared to domestic payment systems.

Figure 2. Breakdown of international trade costs



Source: WTO calculations using World Input-Output Database data and methodology from Chen and Novy (2011), data from 2014.

6. *First, the international payment infrastructure is largely dominated by a few large players constituting the so-called correspondent banking system*. Payment Service Providers (PSP) and international banks having a presence in several countries – or correspondents – settle international claims on their own accounts across borders. Correspondents totalize roughly 90% of cross-border payment volumes, the remaining 10% being covered by the marginal presence of Money Transfer Operator (MTO – e.g. Western Union). Further, the FSB indicates that 45% of surveyed banks rely on two or fewer correspondents for more than 75% of the value of their wire transfer. This concentration around correspondent banks is even higher for small and medium banks. Such market power can have potential negative impacts on costs and efficiency, especially for smaller banks more vulnerable to abuses from dominant positions (FSB, 2018[6]).

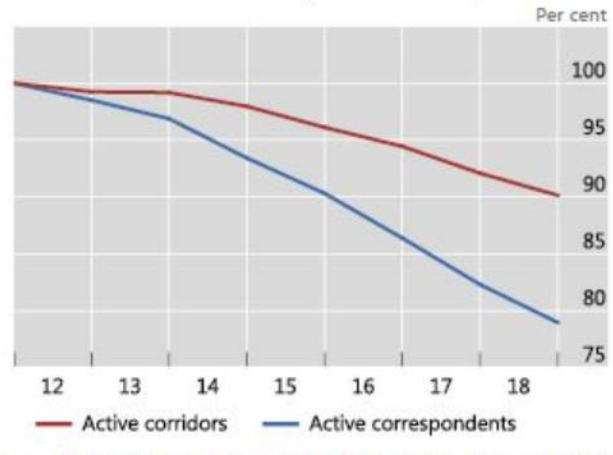
7. *Second, international payments remain costly compared to domestic payments.* In particular, banks realize larger margins on international transactions, nearly 20 basis points (bp) against 2 bp for domestic transfers (McKinsey, 2016[7])**.** The impact is particularly large in Low and Middle-Income Countries (LMIC), where remittances have become the main source of external financing, surpassing FDI flows in 2018[5]. While the global goal for the cost of remittances has been established at 3% in the Sustainable Development Goals for 2030, the current global average stands at 7%.

[5] Remittances flows in LMIC are evaluated at USD 462 billion, excluding China compared to USD 344 billion for FDI. Remittances on track to become the largest source of external financing in developing countries, (WBG, 2019[41])

8. *Developments over the past few years exacerbated the risk of exclusion for LMIC from global markets* as reflected by the decline of correspondent relationships in many remote regions (Durner and Shetret, 2015[6] - Alwazir et al., 2017[7]). A yearly analysis performed by CPMI has shown that correspondent banking relationships were in severe decline since 2012, as open correspondent corridors and active relationships have declined respectively by 10% and 20% from 2012 to 2018 (Figure 3) despite a relative surge in volume of cross border payments (Rice, van Peter and Boar, 2020[4]). Such reduction in services has been driven by several factors:

- The increase in the compliance burden has discouraged banks to manage less profitable correspondent relationship (BIS, 2018[8]). Especially, the necessity to engage and manage AML/CFT measures incl. the costly "Know Your Customer" (KYC) procedure have put pressure on the back-offices of correspondent banks reducing the overall profitability of the relevant business line (Breslow S., Hagstroem M., Mikkelsen D. and Robu K., 2017[9]),
- Correspondent banks generally adopted a lower risk profile to adapt to new post-GFC regulation (for which greater capital is required for riskier activities), notably discouraging them to engage in jurisdictions where comprehensive due diligence of respondent banks (receiving the funds) could not be enforced (IMF, 2017[10]).
- The degree of integration of information and communication technology may foster interconnections between international and local payment service providers. Less integrated jurisdiction are thus suffering from reduced competitiveness, which often cause the reduction in active corridors (BIS, 2020).

Figure 3. Cumulative decline in correspondent banking



Source: New correspondent banking data - the decline continues, (BIS, 2018[8])
Note: In the context of international money transfer, bilateral relationships exist between countries, in the form of active corridors, generally operated by SWIFT, or between banks, forming active correspondents.

9. *Finally, the lack of interoperability between domestic payment systems makes cross-border payments slow and expensive compared to domestic payments*. If not regulated under a harmonized payment area, such as the Single Euro Payment Area (SEPA), international payments rely on specific bilateral relationships, which are less efficient as they raise legal, regulatory, and technical issues (ITU, 2016[11]). The lack of interoperability is even more salient for LMICs, which report interoperability of their Automated Teller Machines (ATM) and Point of Sale (POS) between countries at roughly 50% compared to 86% for high-income countries (WBG, 2012[12]).

2.2. Recent public and private sectors initiatives have improved the current cross-border payment system

10. Recent innovations in exchange of information and digital repositories present the potential to raise the global efficiency of international payments by reducing the cost of cross-border transactions while increasing their speed of execution. A number of private and public initiatives have in particular emerged.

11. *Correspondents are undertaking collective initiatives to lower the transaction costs of international trade*. The pooling of customer regulatory information has been integrated in bank processes and should result in lower compliance costs (e.g. KYC depositories). Additionally, a sector-wide harmonization is being conducted by commercial banks and PSP to establish global standards for payment messaging (ISO 20022 or SWIFT Global Payment Initiative) facilitating cross-border messaging while ensuring payment transparency.

12. *Fintech is gaining momentum especially in Europe*, where non-banks payment systems received close to EUR 4 billion in investments each of the past two years (+529% from 2013 investment level - Bruno, Denecker and Niederkorn, 2019[12]). They specifically tackle the retail segment by offering less costly and more transparent transaction services. This growth is mainly driven by two factors: the global expansion of online commerce and relative lower compliance costs, spurring from a more lenient regulatory regime, as most do not register as banks. If a complete substitution is not yet to be considered, this competitive pressure however applies a downward trend on prices and fosters operational innovation in the market.

13. *Central banks shoulder the harmonization of the cross-border payment infrastructure by improving the interoperability of national payments infrastructures*. The US have been able since 1999 to open its domestic system to cross-border payments by extending Automated Clearing House (ACH) services to foreign banks. As an example, since it joined in 2003, Mexico has processed USD 2.6 billion worth of cross-border transactions (BIS, 2018[8]). These initiatives are however not widespread, notably because they feature lower margins for participating banks, making them less attractive overall. Central banks are also increasingly researching DLT-interoperability to link Real-Time Gross Settlement (RTGS) systems across the globe, yet initiatives of that type have not been fully adopted (see Box 2).

14. *International standard-setting agencies are actively researching common measures to address the above-mentioned frictions*. Noted advances under the G20 mandate of the FSB to address the continuing decline of active corridors has focused on harmonizing regulations in national jurisdictions. Empirical research has recently shed light on the causes of de-risking and confirmed that the loss of a corridor was correlated with FATF country high-risk profiles, yet interestingly enough also with their level of technological integration (Rice, van Peter and Boar, 2020[4]).

Box 2. Public initiative of DLT-based international settlement system

The Bank of Japan and the ECB's project ("Project Stella" – ECB, BoJ, 2019[12]) aims at leveraging interoperability of DLT in different currencies. Such system would rely on pre-funded deposit accounts, conditional payments and guaranty lines. Just as for domestic payments, a central ledger would be operated based on these prefunded accounts and exchanges would be performed and recorded irrevocably on the ledger. However, the project does not elaborate on the creation of a dedicated token.

The Monetary Authority of Singapore (MAS) jointly with the Bank of Canada and the Bank of England have developed several models establishing a framework to use DLT in cross-border payments ("Project Ubin" – BoE, BoC, MAS, 2018[12], Shabsigh, Khiaonarong and Leinonen, 2020[12]). These models focus on the interoperability of decentralized ledgers to allow CBDC to be used for cross-border payments:

- In a first model, central banks would issue CBDC against their local currency on specific accounts opened by private entities – probably correspondent banks. The latter would hold accounts in multiple central banks to satisfy consumer demand in a varied range of currencies. This approach would provide a good technical solution to reduce both operating costs and settlement time as transactions would be performed within a single decentralized ledger. However, it would not significantly reduce the transaction costs associated with the system of correspondent banks, which is mainly driven by the regulatory reserves required when dealing with high-risk countries (as per Basel regulation).
- A second model explores potential agreements between central banks to operate CBDC accounts accessible to any participating banks. Practically, a ledger would exist for each currency in the monetary agreement and banks could directly access a foreign currency, without relying on any system but the DLT network, thus speeding up the process and potentially reducing fees to be paid to multiple actors. The foreign exchange rate would be determined by fractional reserve of the participating central bank's currency.
- Finally, a last model envisages the creation of a universal international currency, similar to the model of the stablecoin (reviving the idea of Keynes' bancor), against which all currency would be quoted. Central banks and banks alike would open accounts on the DLT-operated networks and would trade the currency in line with their client's need. Exchange rates would be determined by fractional reserves.

2.3. Stablecoins could potentially increase efficiency of cross border payments but their wide adoption would come with several risks

15. Created in 2014, stablecoins are crypto-assets aimed at operating payments on Distributed Ledger Technologies allowing for peer-to-peer transactions . They are designed to address the most salient setback of crypto-assets, their price volatility, which prevent them to be used as a stable medium of exchange and unit of account, two fundamental characteristic of currencies. To do so, the price of the coin is anchored to a pool of assets. Stablecoins may use different mechanisms to stabilize prices: backing their value on assets or on algorithms controlling the supply of new stablecoins to preserve the value of existing coins (FSB, 2020[13]).

16. Though their adoption as a new means of payment has been so far limited, their characteristics give them the potential for a more widespread use. Stablecoins could potentially represent an alternative means of payment for international settlement, bypassing the current correspondent banking system. Practically, one buyer would be able to purchase goods and pay in stablecoins, which could in turn be exchanged for an equivalent amount of fiat currency reflecting the price of the currency relative to the

basket of currencies of the stablecoin. This process may increase the efficiency of cross border payments by reducing transaction costs.

17. The use of a global medium of exchange is not a new phenomenon and has been undertaken by several national currencies. However, the specificity of crypto-assets lies on the fact that they can be used at the same time as a means of payment, competing with national currencies (Benigno, Schilling and Uhlig, 2019[14]). Such configuration would impose drastic change on the existing financial system if largely used, the consequences of which remain to be formally assessed by regulators, in particular with respect to exchange rate, monetary and competition policies.

2.3.1. Exchange rate policies: a potentially less efficient market clearing

18. With a crypto-asset used in parallel with national currencies, the fiat FX market would potentially clear less efficiently due to the lag induced by the currency being exchanged for stablecoins instead of another fiat currency. Market clearing would be suborned to the stabilization mechanism of the stablecoin based on an algorithm. The efficiency of the latter remains to be proven effective under minimal market depth and low liquidity in asset reserve markets. Central banks may hence face difficulties in implementing their exchange rate policy.

19. Another concern relates to the capacity of a private actor to maintain the desired level of the peg, as claimed (Bullmann, Klemm and Pinna, 2019[15]). Similarly, to maintain fiat currency pegs, stablecoins need to balance their collateral (foreign exchange reserves) on a continuous basis, to stabilize the coin value. Stablecoins algorithms have not yet proven capable of maintaining the peg value. Without the insurance that the pegs could be maintained by liquidity injections, stablecoins would require a lender of last resort to secure trust in the coin value, as is the case for any fiat currency (Schich, 2019[16]). Yet, such facility comes at the costs of heavier regulation, and dependence on a central agent, which intrinsically opposes the initial motive for the development of stablecoins.

2.3.2. Monetary policy: a dilution of the monetary policy channel

20. A widespread adoption of stablecoins would immunize the economy from central bank intervention, very much alike what is observed in countries facing high levels of dollarization. In particular, high-inflation currencies could see their citizens shifting towards the stablecoin to pay domestically thus creating a type of dollarization of their economies. The reduction in banks' deposits, turned into stablecoins, would therefore render monetary policy, based on the two-tier system, less efficient in accommodating exogenous shocks through the interest rate channel (Edwards and Igal Magendzo, 2003[17]). In addition, economies featuring a partial integration of stablecoins in their payment systems would also suffer from any appreciation of the external currencies, causing output to contract on accounts of higher stablecoin-denominated costs. Experience from dollarized economies has shown that an appreciation of the US dollar may cause up to 1.5% reduction in emerging markets outputs (BoE, 2017[18])

21. In the current international monetary system, a trilemma prevents the simultaneous pursuit of three policy goals: financial integration, fixed exchange rate and an independence of monetary policy (conceptualised in the Mundell-Fleming framework). In the event of an economic downturn, central banks tend to conduct expansionary monetary policies to pull down the interbank interest rate and foster investments. Under the current system, the decline in the relative interest rate would trigger a capital outflow to more generous jurisdictions, bringing down the exchange rate, boosting imports and fostering additional growth (through the exchange rate channel).

22. The adoption of stablecoins would constrain monetary policy, leading potentially to a dilemma, a situation where countries are forced to adopt synchronous monetary policy, even in the event of free capital flows and flexible exchange rate (Benigno, Schilling and Uhlig, 2019[14]). This comes from the fact that stablecoins by acting as a global currency and at the same time as a mean of payment may be used as a substitute at the local level. The risk of portfolio shift between different currencies through the global money

would increase and imply that currencies would compete indirectly with the global alternative and exchange rates would have to remain constant to avoid a flight towards the global money in payment. Further, if exchange rates remain constant, interest rate parity, which is required when capital movement are free, implies that nominal interest rates should be equalised, and hence monetary policy in the trading countries should be synchronised. Such a synchronisation has been adopted in certain regions, with proven benefits (source BCE), yet if stablecoins were to be prevalent at the global scale, countries may find themselves forced to such synchronisation. In practice, the international role the USD already prevents some jurisdiction to conduct an independent monetary policy.

2.3.3. Competition policies: the risk of dominant market position abuses[6]

23. The entry of tech giants in the payment services market may reduce its contestability. These firms gain dominant position in international commerce by concentrating the operations of the market place on their own platforms, from advertising, to payments and potentially lending. Indeed, tech firms' business model is based on Data analytics, Network externalities and interwoven Activities (DNA), which allow them to benefit from network effects. Simply put, adding additional users to the network increases the value to each user, notably through accessibility to a wider variety of individuals. These positive returns to scale usually create large barriers to entry and foster a "winner takes all" risk on this specific market. Furthermore, tech firms collect and manage user data with more efficiency than banking actors, due to the inherent benefits of user to transmit data to the platform. Lastly, a decline in the use of cash might further reduce the market contestability of payments; in the event of no alternative public option, consumers could be subject to oligopolistic behaviour from payment infrastructure providers. Against this background, a first challenge relates to consumer data protection, while a second critical issue relates to the need for new regulatory measures if tech firms are able to recourse to predatory activities.

3. The opportunity of CBDCs to address local payment systems challenges

3.1. Brief overview of domestic wholesale payment infrastructure system: efficient but liquidity requirements remain high

24. While largely recognised as efficient, wholesale payments have been associated until recently with a trade-off between settlement risk reduction and up-front liquidity requirement for banks. National payment infrastructures are multi-layered and involve a multiplicity of actors in a two-tier model (see Box 3). Exchanging goods and services against cash or deposit claims electronically is made possible by a network of participants, operating transfers on a daily basis. Commercial banks operate large-value payments (LVP), as they deal with larger corporate and financial clients. These payments could generate settlement risk[7], i.e. the risk that a counterparty does not receive its payment, while having disbursed the related securities. As wholesale payments become larger, coping with this settlement risk became paramount.

25. The move from Deferred Net Settlement (DNS)[8] systems, to RTGS wholesale systems in the 1990s' and the progressive adoption of Fast Payment systems for the retail infrastructure since 2000s' (BIS, 2016[19]) have reduced substantially the settlement risk associated with payments. RTGS systems

[6] A wider analysis of the regulatory challenges and policy options on the topic have been explored by the OECD and its Delegates within the Competition Committee in June 2019 and the Committee on Financial Markets, which summarizes its conclusions in a recent paper (OECD, 2020[59])

[7] BIS Glossary: settlement risk pertains to: "the risk that settlement in a funds or securities transfer system will not take place as expected"

[8] DNS aggregated daily transactions to net opposing positions and reduce liquidity intensiveness of wholesales payments, yet building up credit risk as open positions increased.

are dedicated platforms operated by central agents, allowing the immediate execution of wholesale payments in central bank money. Such systems, as the European TARGET2 or the U.S. Fedwire Funds Service execute real-time settlements in central bank money. Settlement risk is then reduced as reserve pre-funding ensure the availability of funds, while dealing in central bank money protects the transaction from the default of the operator, as central bank are virtually immune from default in their own currency. By 2016, roughly 80% had implemented forms of RTGS.

26. Yet, the large adoption of RTGS systems, and the associated lower credit risk, has come at the cost of higher liquidity needs for commercial banks (Banque de France, 2019[20]). Indeed, RTGS systems require individual accounts to present the available funds to settle the transaction. If the funds are insufficient, the transfer is not performed or the payer needs to drawdown a credit line, often collateralized.

27. Furthermore, the system is only operational during central banks opening hours, as outlined in the table below for 6 RTGS systems (see Table 1), which reintroduces settlement risk in the system. The collateralization of intra-day liquidity provided by central banks indeed causes mispricing as central counterparties shift their liquidity drawdown towards the end of the day, to save costs (Pfister, 2018[21]). To cope with this development, some central bank actively research full availability in their RTGS systems. For instance, the European Central Bank (ECB) TIPS operates pre-funded accounts, which can perform settlements on a 24/7 basis but those accounts are funded only during the opening hours of the ECB and do not feature netting mechanisms. [9]

Table 1. RTGS systems opening hours

	Australia	Colombia	Eurozone	Norway	United Kingdom	United States
Operating hours (local time):						
Opening time:	07.30	07.30	07.00	06.40	06.00	21.00 (ET) the previous calendar day
Close for customer transfers:	16.30	20.00	17.00	No standard cut-off times	16.00	18.00 (ET)
Final close:	18.30	20.00	18.15	16.30	16.30	18.30 (ET)

Source: (Allsopp, Summers and Vaele, 2008[22])

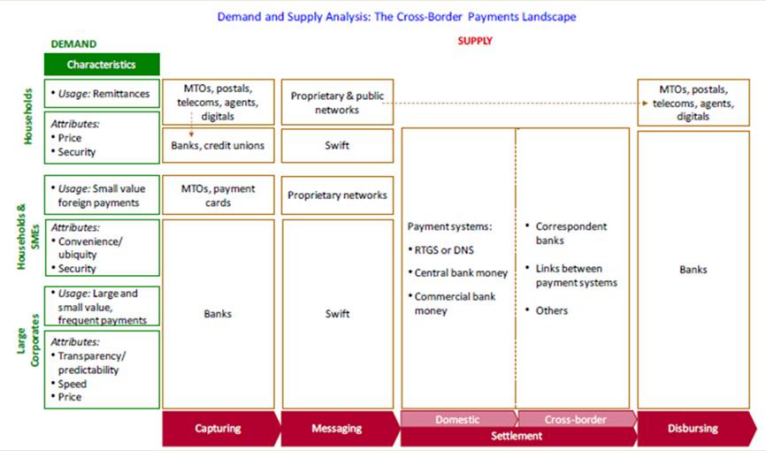
Box 3. Functioning of domestic payment systems: brief overview

In essence, payments can be divided into four subsequent steps (IMF, 2017[10]): *capturing* the trade order upon client need expression, *messaging* the transfer order to the relevant banks via a PSP, *settling* accounts between domestic banks and cross-border ones, while finally *disbursing* the funds (see Figure 4). At its core, this payment infrastructure is divided into two tiers: retail payments, which are operated between individuals on commercial banks' books and wholesale payments, operated between commercial banks on central bank's books.

[9] Netting is the process of offsetting the value of opposing positions or payment due to be exchanged between several parties. It generates credit risk and liquidity during the time the position remains open.

- At the retail level, electronic payments are performed through instruments, allowing transfers between individual bank accounts. These include direct transfer orders, credit or debit card payments, or any payment performed via PSP (usually used for online payments). In substance, these instruments record and communicate transactions so that cash is debited from the buyers' account and credited on the seller's account in a timely manner. Payment instruments therefore materialize transactions by a debit and a credit order issued to each bank.
- Once accounting entries are recorded by each bank, a subsequent transfer among commercial banks is performed in central bank money to settle the transaction. Commercial banks are indeed required for prudential purposes to hold a set percentage of their deposits at the central bank as reserves, which are then used to perform such transfers to reduce settlement risks (see infra). Once the transfer orders are received, the central bank executes the transaction by debiting one commercial bank central bank's reserve account and crediting another. Only systematically important commercial banks have a central bank account, the banks, which do not have access to central bank accounts exchange currency from their own bank account, hold an account in larger banks.

Figure 4. The Payment Chain



Source: (IMF, 2017[9])

3.2. New technologies have the potential to increase further the efficiency of wholesale payment though the overall gains appear limited

28. Wholesale CBDC would represent a design increment to central bank money, which could present opportunities to reduce further intermediary costs and liquidity needs associated with the current RTGS systems[10]. This type of CBDC would exclusively aim at facilitating the exchange between the central bank and its designated central counterparties (systemically important commercial banks having access to the central bank's balance sheet through reserve deposits), within the interbank market. The main evolution from the existing system would be the migration from a gross system with partial availability to a netting system, featuring complete availability. Enhancement to the current system could be as follows:

- *Liquidity needs:* prefunded individual accounts performing netted settlements could reduce the daily liquidity needs of the interbank market. By allowing the netting of intraday transactions, commercial banks would optimize the use of high quality assets immobilized in repo transactions. Reducing the daily liquidity needs could enhance the volume of exchanges, in particular when the economy faces a liquidity drought (Garrat, 2016[23]).

[10] Although not within the scope of the papers, the authors recognize similar appetite for DLT existing in other capital markets, such a equity payment, to facilitate the settlement cycle or delivery versus payment (BIS, 2020[58]).

- *Settlement risks:* this system would operate under minimal settlement risks, as transactions would be conducted in central bank money, immune to default in its own currency.
- *Complete availability*: a fully available system performing settlements on a continuous basis (without the constraint on opening hours) would be achievable through automated ancillary systems.
- *Intermediary costs*: the system could reduce the need for intermediaries, namely PSPs, if all client transactions are performed on a shared and synchronized ledger. This would shrink back-office costs of record keeping and internal reconciliation by reducing the need for human intervention (Bech et al., 2017[24]) .

29. However, the DLT efficiency remains to be proven efficient and scalable (Annex A). The execution speed of current DLT-systems would not support LVP, notably due to lags in the validation process. Furthermore, no project large enough has been realized to test for the significance of cost-effectiveness of DLT, despite some interesting proof-of-concepts (see Box 4).

Box 4. The Canadian CADcoin proof-of-concept and policy research

In 2016 the Bank of Canada (BoC), jointly with Canada Payments and the R3 Consortium have developed a pilot for its own CBDC: the CADcoin[11]. Their goal was to achieve operational efficiency through the creation of a wholesale currency, notably aimed at reducing back-office costs for users and the liquidity needs associated with RTGS systems. Indeed the Canadian RTGS system mobilizes an increasing amount of liquidity, as roughly a tenth of the Canadian GDP (USD 175 billion) is exchanged daily in central bank money.

The CADcoin is a DLT-operated central bank money based on Digital Depository Receipts (DDR) that act as a pre-funded central bank zero-interest bond sent to the receiving counterparty. Transactions are netted and settled throughout the day until a "cashing-out" phase, which updates banks' positions in the CB accounts. In essence, the BoC let central counterparties credit a segregated account on its books, in exchange for DDR to be spent during the day. Further, because the money is deposited at the central bank, in its own currency, the credit risk would remain virtually nil. Liquidity needs are then reduced as DDR allow for the netting instantaneously of commercial banks transactions, supporting higher volumes of transactions.

Overall, the project demonstrated how successful DDR could be used for settlement of securities on a multi-issuer ledger where coins are specialized to reflect central bank issued cash or security. However, the BoC recognizes that the project's scope was not sufficiently large so as to detect significant cost-saving opportunities related to the use of DLT[12].

[11] Several sources relay presentations and analysis of the project, notably (Bank of Canada, 2017[46]) (Chapman et al., 2017[47]) (Bank of Canada, 2018[48])

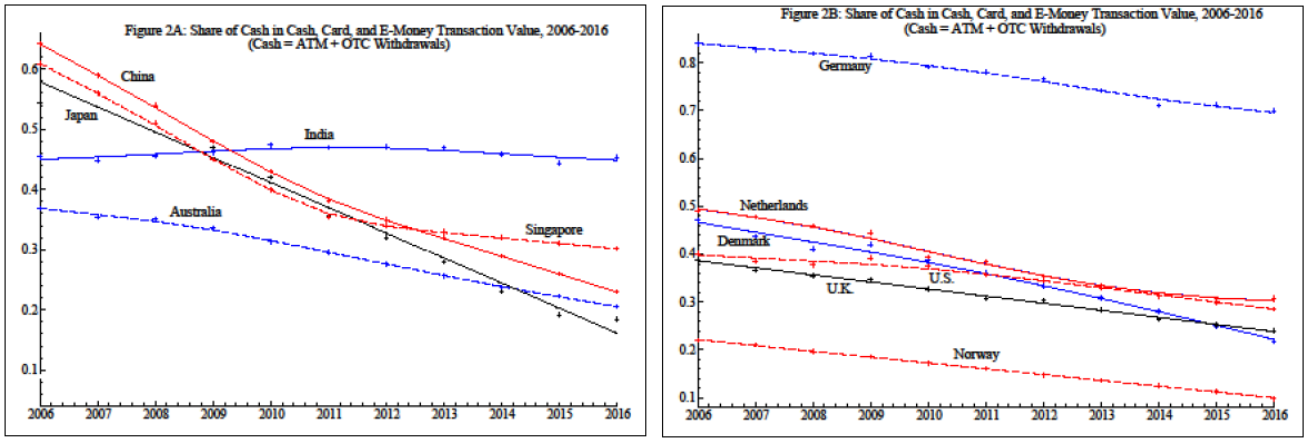
[12] Additionally, a legal framework is needed. In 2018 roughly 75% of central banks did not know or did not have the capacity to issues a new legal tender for a wholesales CBDC (Barontini and Holden, 2019[49])

3.3. A universal CBDC could answer the decline in the demand for physical cash, yet with some profound economic implications

3.3.1. Demand for means of payment and store of value proves increasingly digital

30. The decline of physical cash as a means of payment to the benefit of electronic money is noticeable in several developed countries. From 2006 to 2016, the share of transactions paid by cash declined: depending on the computational method, the yearly average reduction ranges from 1.3% to 2.2% across 11 countries and is forecasted to decline further at an annual average rate of 1.4% by 2026 (Khiaonarong and Humphrey, 2019[25]). Compositional changes in the population drives this trend as younger adults use digital currencies (cards and mobile phones) for payments more often than physical ones[13]. Yet, cross-country differences in the use of cash remain large; Germans pay with cash for almost 70% of total transactions in cash, card and e-money, compared to 10% for Norwegians (see Figure 5). The decline in the use of cash is associated with several opportunities and risks (Box 5).

Figure 5. Share of Cash in Cash, Card and E-money transaction value in 11 countries, 2006-2016



Source: **(Khiaonarong and Humphrey, 2019[25])**

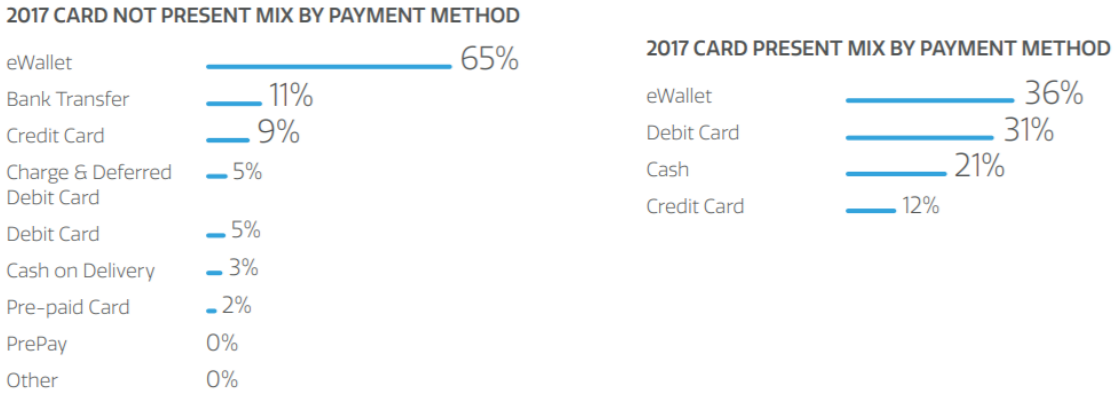
3.3.2. An increasing role of digital cash providers, especially in emerging economies

31. Accompanying the rise of online commerce, new payment systems have emerged and became widespread in some economies. These systems, more prevalent in developed economies, operate as overlay systems that relay the existing payment infrastructure (e.g. Paypal, Apple Pay). Alternatively, some platforms have developed a settlement system in-house, which features proprietary wallets (e.g. M-Pesa, AliPay, WeChat Pay - BIS, 2019[20]). While the former remain limited in use (ApplePay in the US only penetrates circa 7% of the population), presumably due to the established credit card infrastructure, the latter has experience staggering growth in the past years. AliPay and Wechat Pay respectively accounts for respectively 500 million users (36% of the Chinese population) and 900 million (65%), together realizing 94% of mobile payments in China. These new systems are now dominating payments in China, with a 36% of "card present" payments method (based on the credit card infrastructure) and a staggering 65% of "card not-present" payments (see Figure 6). Nonetheless, the People's Bank of China has been active in

[13] Here results for India could be counterintuitive as both birth death rate stand high. According to "Beyond Cash", (USAID, 2016[50]) these results might be due to the lack of penetration of digital infrastructure – "only 21%of these who earn digitally can save money in a bank account" – and the resulting low acceptance of digital means of payment by merchants.

the development of a pilot CBDC has launched public digital wallet in four major cities to try and attract a share of Chinese mobile payments.

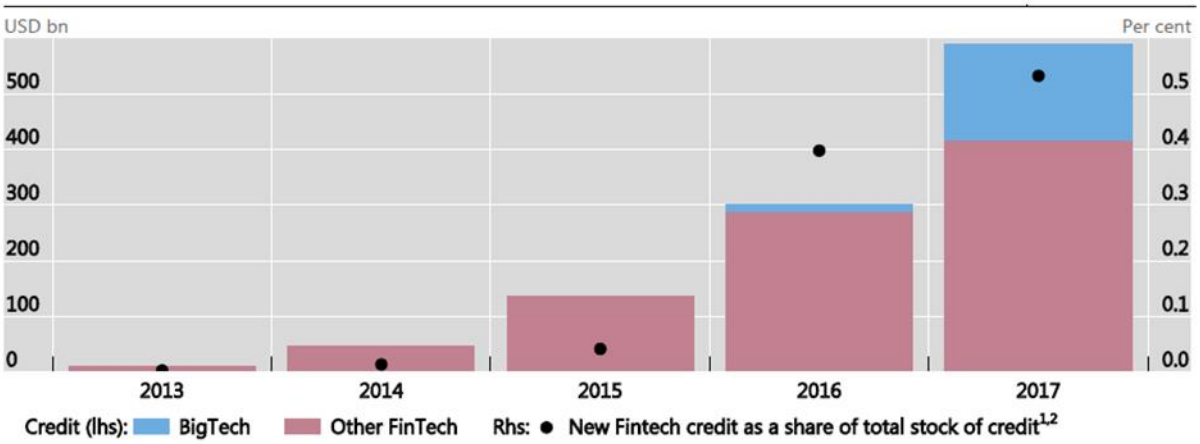
Figure 6. Retail payment method mix in China (2017 figures)



Source: (Worldpay, 2018[26])

32. These platforms generally operate as money market funds (MMF), wherein they store and invest currency deposited in productive asset (generally repos or treasury bonds). Thus, they provide users with a store of value, alternative to banks' deposits. In China, these tech firms have grown to represent a significant part of traditional short-term funding, to such an extent that the Chinese government developed a dedicated Clearing House to manage and secure these flows. A few of them actively engage in lending, however this activity remains small relative to the global credit to private actors (less than 1% of total credit – see Figure 7 - Frost et al., 2019[21]).[14]

Figure 7. Global credit from Tech firms (2013-2017)



The bars indicate annual global lending flows by BigTech and other FinTech firms over 2013-2017. Figure includes estimates.
[1] Total FinTech credit is defined as the sum of the flow of BigTech and other FinTech credit. This is then divided by the stock of total credit to the private non-financial sector. [2] Calculated for countries for which data were available for 2013–2017.
Sources: Cambridge Centre for Alternative Finance and research partners; BigTech companies' financial statements; authors' calculations.

Source: (Frost et al., 2019[27])

[14] Big Tech and the changing structure of payment services, BIS, 2019

Box 5. The potential risks and opportunities associated with the decline of cash use

Central banks bear the responsibility to maintain the cash infrastructure of their given currency, which involves costs related to printing, designing, delivering and replacing notes, among others. They earn in turn interest payments on the total of banknotes issued. Stronger efficiency gains related to the maintenance of a physical infrastructure are potentially associated with the digitalization of money. It is also associated with several potential gains related to a better traceability of payment, reducing the possibilities for tax evasion (in particular for VAT schemes), and other illicit financial flows.

One direct consequence of the decline in the use of cash is hence to lower seigniorage income (interest paid by banks in exchange for accessing central bank money) that can be quite substantial depending on the structure of the money demand. For instance, it ranged between USD 1-2 billion since the year 2000 at the Bank of Canada (Engert and Fung, 2017[28]).

Further, the decline of cash and a potential substitution towards crypto-assets may be ultimately associated with financial risks. In the theoretical case of a cashless society, e-money and deposit would not be convertible into cash. The different forms of money would behave as financial assets, with their value against each other being continuously reassessed. The different forms of money would become an imperfect substitute and financial fragility could increase as the risk of runs from some form of currencies emerge (Landau and Genais, 2018[29]).

Finally, an effective decline in cash use would ultimately reduce the privacy of consumers' spending. As such, if effects of privacy on spending patterns remains debated (Acquisiti, Taylor and Wagman, 2017[30]), government shall carefully define the means permitting the protection of consumer data.

Those risks related to the decline of cash are additional arguments feeding the debate about the opportunities to issue a CBDC in order to preserve demand for central bank liability and related seigniorage income.

3.3.3. A generalized access CBDC is likely to disrupt the financial markets, yet with potential considerable benefits in the conduct of monetary policy

Risks for financial stability in the deposit market and for economic growth

33. The provision of a risk-free option in the deposit market is likely to increase the risk of bank run from private actors to the central bank option, unless protective dispositions are taken to counterbalance these effects. The threat of bank runs exists due to a lack of trust from consumers in a bank (or a group of banks) relative to their central liability (i.e. cash). By extending the access to a risk-free bank liability (central bank money) through a CBDC, central banks would increase this threat. Different options would exist to dampen this risk, notably by designing restrictions or disincentives to portfolio shifts. First, promoting a financial safety net should preserve trust in the system, in the event of a crisis. Among others, remaining *lenders of last resort* to immunize the economy from systemic risk losses, as well as protecting consumer accounts through *deposit guaranty schemes* would be crucial for central banks. Second, central banks could also impose portfolio ceilings and dynamic transfer fees in order to curb portfolio movements, which

could take the form of a volume fee, on the number of transactions, or a value fee, on the amount transferred (Mancini-Griffoli et al., 2018[31])[15].

34. The introduction of a public digital currency and the new deposit role of central banks would reduce financial market intermediation and potentially lower the profitability of the banking sector. The possibility for consumers to satisfy their demand for deposit via a risk-free asset is likely to reduce banks' main funding through deposits. In the current system, banks carry out transformations of short-term liquid deposits to long-term, illiquid investments for individuals or firms to spend. Banks would however retain the capacity to create money, through seigniorage-financed lending[16], yet this funding capacity remains regulated by central banks' reserve requirements (as a percentage of deposit held). With the creation of a digital deposit, the central bank would reduce banks' deposit and thus further deprive the banking sector of its second core funding mechanisms. Banks may then turn to commercial paper or equity for additional funding, yet these are likely to be more costly and less stable, since the banks would retain the most junior share if a credit event occurs.

35. Introducing an interest-bearing CBDC may further deepen financial market disintermediation, unless the supply of lending has the capacity to adapt. If an interest-bearing CBDC is introduced, the rate duly set by the central bank would constitute a floor to the market rate due to the risk-free characteristic of the central agent. This would influence the other actors in the deposit market; to remain competitive banks would need to increase their deposit rate vis-a-vis this risk-free option. This situation would shift up the supply curve faced by individual banks, as competition increases and would wage a subsequent reduction of banks' margin, especially if the price hike cannot be fully passed on to the lending rates (Box 6). Yet, if banks hold sufficient market power, it would be possible for them to pass on more of the additional cost to their lending rate, thus protecting their profit margin, and increasing their activity, by attracting more deposits (Mancini-Griffoli et al., 2018[31]). However, as higher funding costs cascade into higher loan rates, potential adverse impact on economic growth may arise.

Box 6. Potential increase in the lending rate, proof from the US and Canada

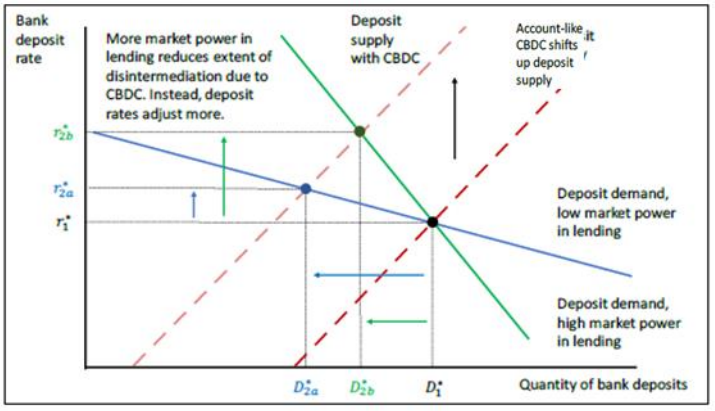
The introduction of an interest-bearing CBDC could positively affect both the lending rate and the output of banks if it increases the demand for deposit and conditional to the existence of sufficient prudential measure that would reduce the risk of too high substitution to the CBDC. If the CBDC rate, taken as alternative deposit rate, floors the market, then other actors would adjust up their rate to increase total demand for deposits. This demand would then be turn into additional lending. Simulations based on US and Canadian data suggest that an interest-bearing CBDC would wage up to 3.55% increase in the lending amounts and the total output by up to 0.5% (Chiu et al., 2019[32]).

The conclusions above however remain ambiguous, since under existing conditions, banks would likely protect their profitability by passing-on any increase in deposit rates onto lending rates if they hold sufficient market power as outline above. The resulting increase in interest would likely reduce growth in output, rather than increasing it.

[15] It should be noted that regulators should question the fairness of such a fee with regards to income inequality, not to disadvantage less endowed households.

[16] Commercial banks can create money through accounting by granting a loans and subsequently providing the funds in deposit account. Hence, the banks' balance sheet remains balanced and money, under the form of a deposit can be expensed in the real economy. It is called seigniorage as in this case, the banks' liabilities (deposit accounts) is used as currency.

Figure 8. Effect of CBDC and market power in lending



Source: (He et al., 2017[33])

36. Depending on its design (see Box 7), account CBDC has hence the potential to weaken the overall prominence of commercial banks in the financial sector, to the benefit of central banks with two potential risks for economic growth, a reduction of the allocative efficiency of credit and a potentially negative impact on lending (Greenwood and Jovanovic, 1990[26] - Cetorelli and Gambera, 1990[27]). In order to reduce this risk of disintermediation, central banks could hence substitute retail deposits and lend directly to banks the money transferred to CBDC (Mancini-Griffoli et al., 2018[31]). By disentangling the deposit and lending activities of banks, central banks would then secure the role of distribution of private actors to allocate credit while still reaping the benefit of a general-purpose CBDC. However, in such a scenario, central banks still need to devise a framework establishing rules of financing for banks, notably aiming at preserving central bank independence, crucial to guaranty the credibility of monetary policy (Bordo and Siklos, 2014[34]).

Box 7. Possible designs for a CBDC[17]

The generalization of the access of a digital central bank liability to the wider population could rely on three distinct designs.

A first option would be to reduce the disruption on the current system by preserving the two-tier system, the banking business model and the existing form of cash. Commercial banks could offer segregated accounts to consumers. Exchanges would then mimic current bank transfers, and be operated by the existing organizational structures. Differences with the current system would lie in the legal arrangements pertaining to the rights of banks over this new form of money and the willingness of regulators to amend the current system. In this scenario, central banks offer an alternative public store of value, under the form of a protected account. Cash could therefore be preserved.

[17] The authors have selected only some of the design scenarios of a generalized CBDC. A more complete analysis can be found in (Engert and Fung, 2017[28])

A second option would be to allow the public to hold accounts directly at the central bank, with potentially stronger effect to lower operating costs and settlement risks while still preserving cash. Under this scenario, the central bank would provide a platform for exchange immunizing the payment system from private actors' credit risk. Any payment performed on the platform would be irrevocable and guaranteed by the central bank. The need for intermediaries would then be reduced, as central banks would undertake a new role as payment system provider for individuals and non-financial firms. It would also need to manage individual deposit accounts in the stead of retail banks. In this matter, overall operating costs could be reduced, as a unique central actor would perform all national transfers and thus would benefit from economies of scale. Importantly, central banks do not currently hold the adequate organizational set-up to achieve these new functions, which constitute an important barrier for the adoption of this scenario. Cash could be preserved under this scenario, yet it would become less useful as most transactions could be performed under a virtually frictionless platforms.

A token CBDC represents the furthest iteration to the current system as it leverages DLT technology to substitute the existing payment infrastructure and the nature of cash. Under this scenario cash could phase out completely and be replaced by a CBDC. Similarly to the wholesales CBDC, all participants in the payment market (in this case, everyone) would hold a wallet from which exchanges would be performed. Each node would also participate in updating the version of the distributed ledger according to defined consensus mechanism. All tokens would then be created either by a transfer of cash or through the validation of this consensus mechanism (see Box 4). This scenario would hence preserve the peer-to-peer characteristic of cash, as DLT systems are based on the authentication and the validation of transactions by the decentralized network and do not require a central database gathering all information.

New tools for monetary policy and new risks for central banks

37. By controlling the rate of return on an interest-bearing CBDC, central banks could gain total control over the market rate, reducing the effect of a credit freeze and ultimately strengthening the monetary policy transmission channel. The difficulties met by Central Bankers to ensure the transmission of monetary policy to the real economy during the last (double dip) financial crisis has highlighted a weakness of our two-tier monetary order. Indeed as the credit freeze occurred in Europe in 2010-2011, banks, unwilling to lend, impeded the transmission mechanism of monetary policy through the interest rate channel and thus prevented the economy from adapting to the severe downturn. Those difficulties would be arguably stronger in a system where the share of privately operated money is larger. By contrast, an interest-bearing CBDC could by-pass central counterparties and communicate rates to the market directly, thus allowing a complete transmission of monetary policy. Because central banks are the safest counterparty in their own currency, any rate they offer is virtually risk-free and thus constitutes the market floor. The rate would then be offered to all, and not limited to a single tier of central counterparties. In essence, CBDC holders would have an incentive to spend or to hoard depending on their expectations on the CBDC rate, thus smoothing potential output gap.

38. An interest-bearing token CBDC could more specifically prevent economies from entering the "liquidity trap", by alleviating the Zero-Lower Bound (ZLB), which was hit by several advanced economies following the Global Financial Crisis (GFC). This barrier to negative interest rate actually exists due to the presence of a zero-interest asset in the economy: cash. Indeed if the central bank sets negative rates, investors would always have the option of holding cash, as a safe asset. This possible "flight-to-safety" thus makes any increase in liquidity inefficient. The possibility of a flight-to-safety disappears if an interest-bearing CBDC supplants cash; central banks would gain immediate impact when applying a negative rate to boost currency circulation. Therefore, only an interest-bearing CBDC, with no remaining cash in the economy would strengthen the efficiency of monetary policy. The latter setting however depends on the

disappearance of the zero-interest option and adoption of CBDC, which in turn, depends on its design. Contrastingly, implementing a non-interest-bearing CBDC (the closest to cash) would only have the effect of raising the lower bound from negative rates to zero (Riskbank, 2018). The current ZLB stands below zero (e.g. -0.4 for the Eurozone) due to the relative burden of holding cash (e.g. cost of moving physical cash, insurance costs). In a digitized environment, there is no such physical slack. A negative policy rate would then always push investors towards holding CBDC instead of Central Bank deposits, effectively raising the ZLB to zero.

39. Finally, an account-based[18], interest-bearing, generalized CBDC would also provide a platform for Friedman's famous "helicopter money" (Engert and Fung, 2017[22], Bordo and Levin, 2017[28]). As popularized by B. Bernanke ((2002[35])), this unorthodox monetary tool aims at combating risks of deflation in a low rate environment by increasing consumer demand, and thus welfare. This fiscal policy measure provides consumers with additional income, financed by newly printed money rather than by the monetization of existing assets, as traditionally undertaken in central bank operations. This emergency income handed over to consumers and businesses would be financed on the central bank balance sheets, rather than by the national treasuries, through write-offs on the asset side or using the subsides of other monetary operations (Galì, 2020[36]). If, on the liability side, helicopter money is distributed under the form of a CBDC, central banks could then benefit from an additional option to overcome the ZLB and further strengthen monetary policy. This could be achieve by setting the interest rate on this newly issued liability or by allowing additional funds to be spent within a definite timeframe, as has been experienced in some Chinese cities piloting retail CBDC.Some argue however, that this solution may prove less efficient that the current targeted monetization of government debt, the latter remaining sovereign in the allocation of fiscal support (Blanchard and Pisani-Ferry, 2020[37])

4. Conclusion

Global trends in international and domestic payments are driven by buoyant innovation that challenges established systems, both in the private and the public sphere. The digitalization of payment messaging and security has helped bringing down some of the existing entry barriers, resulting in acknowledged portfolio shifts towards new virtual assets. We argue that these developments came about partly to cope with existing limitation in payments but also questioned policy makers on the collective actions needed and potential options to address such limitations. The international payment system features the most advanced proof-of-concept and focus primarily on fostering the integration of emerging economies in global trade. On the domestic front, recent crisis have shed light on opportunities to improve the conduct of monetary policy. Overall, central bank digital currencies remains a relatively new field in the economic and financial literature and many questions, notably on financial stability and privacy, remain. In this, it is likely that the numerous projects undertaken in central banks, intergovernmental organization and academia will provide valuable insights in the years to come.

[18] Even though helicopter money could be programmable on a DLT, it may appear difficult to forecast with precision its characteristic, hence calling for a centralized provision of the CBDC to achieve this specific goal.

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Annex A. Technological barriers to the adoption of CBDC for general purpose

Crypto-assets are generally based on a cryptographic technology, which allow all members of a network to certify transactions on a digital ledger. In order to validate new entries to the ledger, blockchain systems may use different consensus mechanisms to select nodes (agents) of the network, which will be responsible for encrypting the next block of transactions. This encryption is called mining, as similarly to its physical counterpart, the encryption is a process of try and error until a cryptographic *hash code* is deemed secure enough for the block to be added to the chain. The computing power used to mine transactions is remunerated by the creation of a token, exchangeable among network participants. Several consensus protocols exists, yet two of them are widespread: Proof-of-Work and Proof-of-Stake. Both of these however present some drawbacks when it comes to being used on larger scale and may not fulfill the expectations of society regarding the delivery of a public good such as a currency

Proof-of-Work, the consensus mechanism popularized by the blockchain underlying Bitcoin. It relies on a competition between all nodes to solve the cryptographic puzzle securing each transaction. The winning node gets the right to encode the next block and is duly remunerated. This mechanism has however been proven extremely energy demanding (O'Dwyer and Malone, 2014[38]). It also tends to concentrate the validation power as the cryptographic code becomes more complex and hence goes against the decentralization purpose of tokenization.

The second most known consensus mechanism is the *Proof-of-Stake*, whereby only one actor is selected to create the code, yet its selection is based on the stake that the actor would put as a guarantee. Namely if the code does not comply with the network requirement, the nodes would lose its stake. This allows only a few nodes in the networks, the validators, to perform updates of the system. This system is especially salient for private use of blockchain; JP Morgan has chosen this mechanism to run its stablecoins: the JPMcoin, which allows customer to send international transfers through a blockchain. If useful for a private goods, this system however centralizes the mining power around the nodes which can contribute the highest stake. Hence in this case, remuneration for the work would fall in the hand of the most endowed, and would leave most other nodes out of the remunerating validation game, questioning the fairness of the system overall

Other mechanisms have been developed, but lack scaled-up examples, despite presenting some useful features for financial sector. We would only mention here the Proof-of-Elapsed-Time protocol, under which all nodes are allocated a random waiting time, at the end of which an individual node is proposed to mine the code, thus increasing fairness of the process.

Finally, in addition to technological inefficiencies, current DLT-operated systems may not be aligned with the prerogative of central banks to control the monetary mass**.** Central banks have been bestowed with the right to print and mint money. Yet from the current examples of cryptocurrency, money creation is decentralized, through mining. Hence by pursuing a token-CBDC, central banks will be required to define specific processes so as to retain this control, potentially defeating the purpose of a decentralized currency. A pilot study from the Central Bank of Uruguay have explored a possible setting whereby the mining process is externalized to a central validator, while the central bank remain in charge of creating tokens. However, such a system questions the efficiency of a token-CBDC, compared with a Central Bank Account, as previously defined.

Annex B. The potential of CBDC for financial inclusion and growth

CBDC might have beneficial implications for financial inclusion by increasing the share of banked consumers in the population. As explained before, an interest-bearing CBDC may have a positive impact on the deposit rate in an imperfect financial market, thus crowding-in consumers in the deposit market (Andolfatto, 2018[39]). Moreover, proponents of CBDC claim that the technology could represent an opportunity for countries to save on the costs of managing their cash infrastructure which are substantial, estimated at about 1% of GDP or EUR 130 billion for a sample of EU countries (ECB, 2013[40]).

By connecting people at a low cost, a CBDC could represent an opportunity for emerging economies to overcome some existing barriers to development through an efficient cash infrastructure. It is indeed very costly to maintain such a network in regions with low density of population or too remote to be connected. Effort to connect through a CBDC have been made by many island countries such as the Bahamas or the Eastern Caribbean, which have both officially launched pilots for general CBDCs. These pilots provide for the involvement of private actors to distribute and operate payments, while the system oversight and the minting process is retained by the central bank. These new forms of central bank liabilities have been released to the public and currently coexist with physical cash.

Yet, if CBDC provide a compelling argument for medium to long term benefits, other systems currently developing might very well serve similar purposes and gain a first-mover advantage in overcoming the barriers to financial inclusion. Private initiatives in mobile payment have emerged, with telecommunication providers offering solutions, especially in Eastern Africa, where M-Pesa now counts more than 30 million accounts. These narrow finance solutions rely on existing infrastructure to provide banking services to countries with a majority of unbanked, such as in India (PayTM) and in China (AliPay – WePay).

To conclude on the topic, we can underline that the potential opportunity of CBDC to increase financial inclusion depends on both the parallel development of a retail banking infrastructure - as CBDC does not provide financial services, as conceived – and political support to increase connection in the wider population. Indeed as argued by the Sveriges Riksbank, turning to a digital currency may exclude the part of the population less inclined to exchange through digital means.