

RISK&OPPORTUNITIES

SG Economics & Sector Studies

Central Bank Digital Currencies: 10 Frequently asked questions

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Central Bank Digital Currencies are new forms of electronic money directly issued by the central bank. They are currently being tested in a growing number of countries, from Sweden to China and France. Whether to address the issue of the disappearance of cash, the threat to sovereignty from private e-money (Libra...), the market power of private payment providers etc., CBDCs are likely to become reality in the coming years.

Yet, all forms of CBDC are not equal. Those available only to financial markets participants (wholesale CBDCs) could magnify efficiency gains from new financial infrastructure technologies, like the DLT. On the other hand, CBDCs available to the public (retail CBDC) could have large impacts on banks and financial stability, especially in times of stress or uncertainty. With the latter, the role of the central bank in the economy could also increase, putting at stake their most important asset: credibility. These impacts need to be well understood and mitigated. Once let out, the CBDC genie would not be easy to put back in the bottle.

1- What is a CBDC?

In their simplest definition, **Central Bank Digital Currencies (CBDC) are any new forms of digital money issued by a central bank¹**. Hence, the following forms of money are *not* included:

- Cash (banknotes and coins) because it is neither digital nor new;
- Reserves or settlement balances held by commercial banks at central banks. Even if they are “digital” central bank money, they are not *new* forms of money;
- Bank accounts used in everyday’s life are digital but are neither new nor, more importantly, a claim on the central bank.

¹ We loosely use the definition proposed by the Bank for International Settlements’ Committee on Payments and Market Infrastructure (“a digital form of central bank money that is different from balances in traditional reserve or settlement accounts”).

The scope of possible forms of money² falling under this definition is still very large, as any CBDC will be differentiable along a few key design features. A key limitation in defining these design features is that the available technologies and use cases are far from settled. Hence, academic research on the subject is very much evolving at the time of writing, even regarding the technical terms used.

Box 1: Central bank money? Private money? Bitcoin? Stablecoin? A short guide

Why distinguishing between money provided by the central bank, private banks, etc.? And how do cryptoassets compare? Here are a few elements to keep in mind:

- **Central bank money** (banknotes, deposits from authorized 3rd parties like banks at the central bank) is the safest available in a given country: it is 100% backed by the full faith and credit of the State, itself backed by its ability to raise taxes.
- **Commercial banks' money** (bank deposits) are as safe as central bank money up to the amount covered by the national deposit guarantee scheme³ (EUR100 000 in the EU). Beyond this, deposits are subject to the bank's credit/liquidity risks, which are mitigated by the various regulations in place (capital ratios, asset quality requirements etc.).
- **Cryptoassets (e.g. Bitcoin)** are not usually considered as money⁴. They are not backed by any collateral nor by any public entity able to levy taxes.
- **Stablecoins⁵** are backed by assets which are initially worth as much as the amount of stablecoins in circulation, plus any assets purchased thanks to the equity put into the scheme by its founders. The risks of the stablecoin are linked to the riskiness of the assets owned by the scheme and generally to the quality of the scheme's governance. Stablecoins are thus riskier than CBDCs issued by countries with sound credit fundamentals.

Keeping these limitations in mind, we retain the following key design features⁶ to differentiate various forms of CBDCs:

- **Accessibility:** the CBDC can be available only to banks and/or financial institutions (**wholesale CBDC**), or to everyone including households and businesses (**retail CBDC** – sometimes referred to as “general purpose” CBDC);

² Note that to be qualified as “money”, the asset considered must be a unit of account (or be denominated in one) and a medium of exchange and a store of value.

³ Although the deposit guarantee scheme can take a few days to reimburse the depositor (e.g. up to 7 business days in France).

⁴ Cryptoassets like Bitcoin or Ethereum have recorded huge price volatility and as such, are neither a store of value nor a unit of account and are seldom used as a medium of exchange. Rather, they have proven to be highly speculative assets (BIS – 2019).

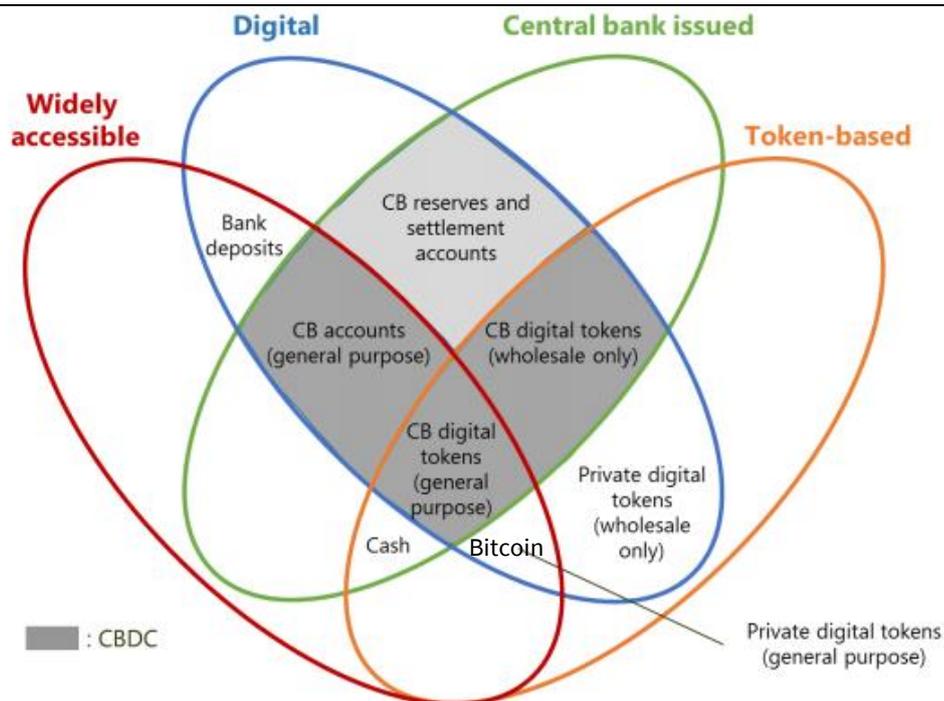
⁵ Stablecoins are cryptocurrencies aiming to stabilize their price by being backed by a pool of assets. Facebook's Libra project is a stablecoin of global reach.

⁶ Dwelling freely on BIS and Riksbank research – see Bibliography

- **Technology:** it can be account-based or token-based. In the first case, the technology rests on a central ledger, with access to the account linked to the identity of the account holder. In the second case, tokens are managed in a decentralised manner and the CBDC belongs to the holder of the token (or the holder of the digital key to access said token – much like a bearer instrument in the physical world)⁷;
- **Anonymity/privacy:** the degree of anonymity is largely dependent upon the above-mentioned access technologies, as accounts are linked to identities while tokens allow for anonymity. However, privacy goes beyond this technology choice as, for example, some token- and DLT- based CBDC architectures could allow third parties to keep records of payment data linked to a customer profile (BIS – 2020).
- **Instantaneity:** payments can be processed in real time and 24/7, or with delay;
- **Remuneration:** CBDC can bear interest – possibly negative – or be without the technical dispositions to do so.

Using some of these features, the Bank for International Settlements (BIS - 2018) has put forward a “money flower” to differentiate three key forms of CBDCs.

Chart 1: The money flower and CBDCs



Notes: CB = Central Bank; general purpose = retail

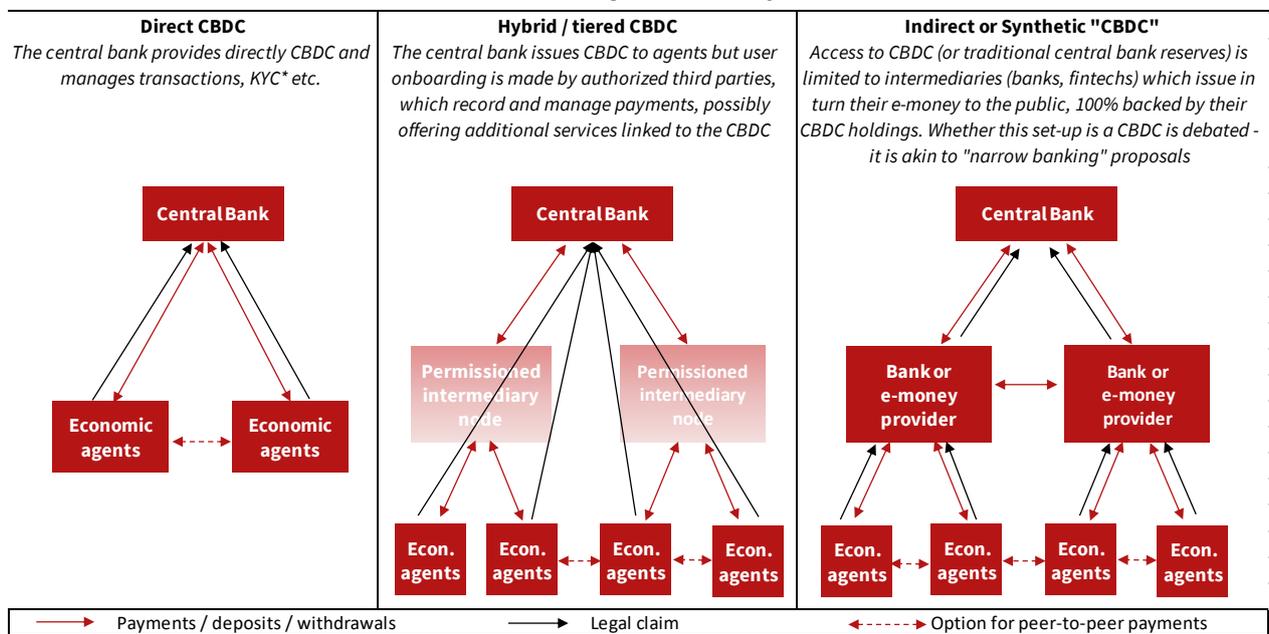
Sources: BIS, Bech and Garrett (2017), SG Economics & Sector Studies

⁷ We retain this classification as “technology”, as used by BIS (2018), although it is subject to debate: it can be argued that the distinction between accounts and tokens is more legal than technology-related (especially since some DLT architectures also refer to accounts).

Two key features are most common in differentiating between forms of CBDC: accessibility and access technology. Hence, most of the analysis focuses on whether a CBDC is a wholesale currency issued by the central bank and relying on tokens, or a retail currency issued by the central bank, whether token-based or account-based.

A final subtlety concerns the architecture of retail CBDCs. Three general types of architecture are generally considered in the literature (see chart 2). The first two architectures are clearly CBDCs: either the central bank directly manages the CBDC payments, or it delegates the right to intermediaries to do so, but in each case the legal claim of the public is directly to the central bank. In the case of “synthetic CBDC”, the public has a legal claim on the intermediary only, although the fact that this claim is 100% back by claims on the central bank is reassuring. The monitoring of this backing, however, would be key.

Chart 2: Architectures for retail CBDC and the question of synthetic CBDC



*KYC = Know Your Customer process

Sources: BIS (Auer-Böhme 2020), SG Economics & Sector Studies

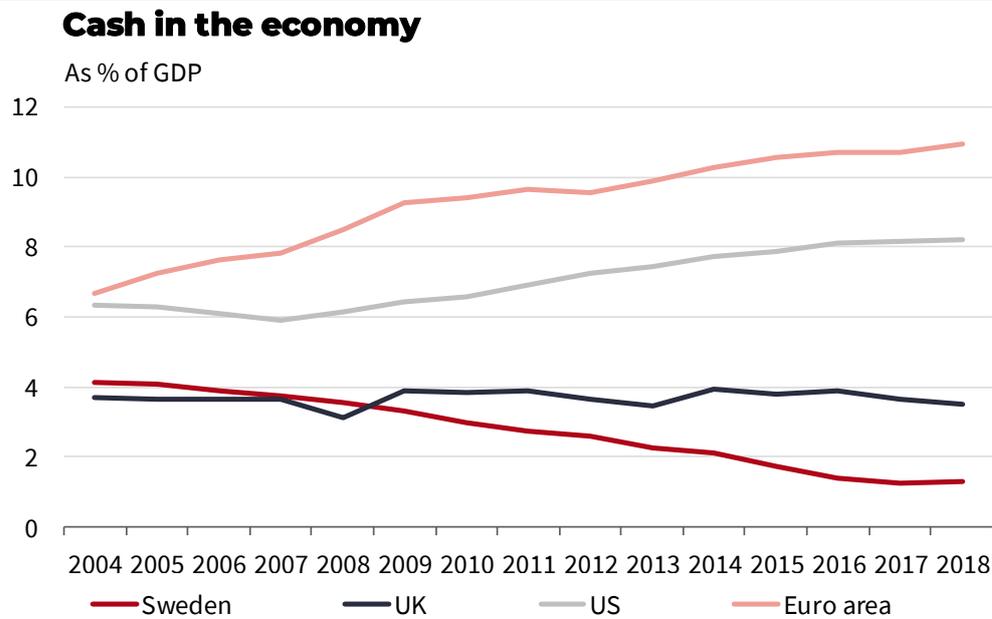
2- What are the advantages of a CBDC?

A major part of possible advantages to a retail CBDC are defensive, in the sense that they would prevent negative side effects should physical cash disappear and/or a private global stablecoin emerge as a key challenger to sovereign currencies (see part 3). However, the possible advantages of a CBDC are obviously linked to the several design choices listed in the previous section, as well as to specific national challenges.

With this in mind, we see the following key advantages.

- **Preserving access of the public to central bank money:** in countries where cash is fast disappearing (e.g. Sweden), a retail CBDC could preserve the public's ability to change private money into central bank money. This possibility has indeed proven to be an enabler for public's confidence in private money. This is also a key factor of economic inclusion for some categories of people currently dependent on physical cash.

Chart 3: Cash is disappearing fast in some countries like Sweden



Sources: Riksbank, ECB, BoE, Fed, SG Economics & Sector Studies

- **Preserving the resilience of a payment system in times of very serious crisis:** public authorities need to provide and maintain a resilient payment network not driven by private interests in anticipation of very dire situations (wars...). This would be more efficient if the money allows for peer-to-peer payments.
- **Preserving competition in payments:** the existence of free public means of payments with basic but modern characteristics serves as an anchor to prices for private-sector payment systems (banks, credit card providers...) and incentivizes differentiation based on innovation.
 - Furthermore, a retail CBDC could serve as a deterrent to the emergence of a global private stablecoin, which could threaten competition. Indeed, the network effects at play for such a stablecoin, especially if backed by very large technology companies, could lead to a natural monopoly giving huge market power to the issuer of this stablecoin.
- **Instantaneity and continuity of payments:** depending on technology choices, a CBDC could allow for instantaneous and 24/7 payments (i.e. the

payment appears immediately on the receiver's balance), including for peer-to-peer transactions.

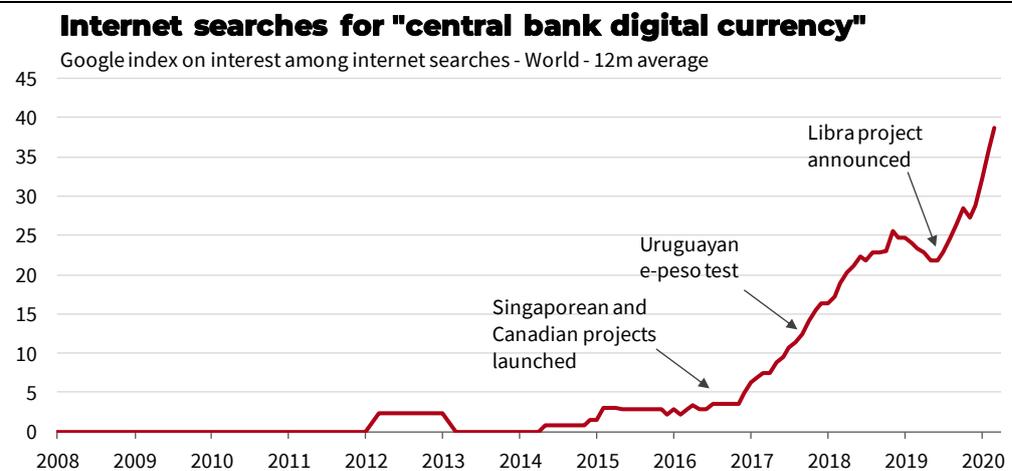
- For retail CBDCs, this would be an improvement upon most bank payments and transfers in most countries. However, several relatively new payment solutions already allow for such features, although generally for solely for domestic payments (Swish, for example, in Sweden).
- For wholesale CBDCs benefitting from international agreements, this advantage would essentially be felt on cross-border payments.
- **Cheaper cross-border payments:** costs for cross-border payments from both households and SMEs are regularly judged as elevated by public authorities, especially in highly-integrated economic regions like the Euro Area. As such, the ECB has recently⁸ threatened to implement a retail CBDC if private-sector initiatives to reduce the cost of cross-border payments in Europe fall short.
- **Enabling atomic Delivery versus Payment:** a tokenized wholesale CBDC would allow to bypass downtimes of market infrastructures and reduce settlement times to 0 for transactions on tokenized assets. Indeed, this fully-tokenized system would no longer require a central operator while also cutting reconciliation issues. Efficiency gains from the ongoing tokenization of financial markets would be magnified.
- **Developing smart contracts:** depending on technology choices, the CBDC can be “programmable”, i.e. include smart contracts. Smart contracts are bits of code (typically inserted on a blockchain) that foresee an action (typically a payment, but not only) conditional upon the completion of a predetermined event (in the real or in the digital world).
- **Increase the international use of the currency:** currencies issued by credible central banks would benefit on this front. In particular, the CBDC should be designed for low costs on cross-border transactions, smart contracts and instantaneous payments (whether retail or wholesale), as well as for full offshore settlement. This is particularly interesting for the euro, whose international role is currently actively promoted by the European Commission.
- **Increasing the range of options for monetary policy:** interest-bearing CBDCs, to the extent that they could reduce physical cash usage, could alleviate or reduce the problem of the “zero lower bound”, enhancing the ability of both the central bank and commercial banks to decrease deposit rates below 0%. In more normal times, changing the interest rate paid on the CBDC in tandem with other policy rates may increase the incentive for banks to pass through the monetary policy decision onto their own deposit rates.

⁸ [*Innovation and its impact on the European retail payment landscape*](#) – ECB, December 2019

3- Why this sudden interest in CBDCs?

The past four years have seen a marked increase in speeches and research papers, as well as in central bank tests for CBDC issuance, in a clear departure from the relative confidentiality of the topic in previous years (see chart below). Recently, the Swedish Riksbank has launched a test for a retail CBDC (e-krona) while the Banque de France launched trials for a wholesale CBDC. The latter started in May 2020, with the issuance of a tokenized covered bond by Société Générale, purchased by the same bank with digital euros issued by the Banque de France, on a blockchain. A list of major CBDC tests planned or ongoing is provided in the section “Is CBDC issuance likely in the near term?”.

Chart 4: The interest for CBDCs is recent and picked up from 2016 as the first projects were launched



Sources: Google Trends, SG Economics & Sector Studies

Two key developments are behind this emergence. The first is technology availability and application. The founding paper for blockchain and bitcoin was published in 2008.⁹ Since then, both the blockchain technology and “cryptocurrencies” have developed markedly.

The second and more recent development is the tentative emergence of stablecoins. Stablecoins differ from first-generation cryptoassets like Bitcoin or Ethereum by being backed by more traditional assets. Stablecoin projects (Libra among them) are thus much more likely to qualify as money, contrary to earlier cryptoassets. As such, they have pressured public authorities and central banks into assessing issues possibly arising from stablecoins and especially from global stablecoins¹⁰:

⁹ « Bitcoin: A Peer-to-Peer Electronic Cash System » - 2008 – Satoshi Nakamoto

¹⁰ The interested reader can refer to studies published by the G7 Working Group on Stablecoins (see bibliography).

- **loss of monetary sovereignty:** beyond monetary policy itself, the competition of an additional money in the domestic economy, issued by a private and foreign institution, would weaken the margins of manoeuvre of public authorities.
- **loss of monetary policy effectiveness:** if a global stablecoin is widely used in a country, monetary policy changes affect a smaller part of the economy, especially if the country's currency is not part of the collateral pool of the global stablecoin. If the latter also facilitate significantly cross-border capital flows, risks of large domestic deposit inflows/outflows would constrain the central bank's decisions.
- **financial stability risks:** these may arise from a mismanagement of the global stablecoin, from sudden inflows or outflows leading to large price swings in markets of assets serving as collateral, etc.
- **monopoly risks:** a global stablecoin can be of a very large size and its footprint on financial, payments, data markets could be large enough to hinder competition.

Given the numerous issues identified, public authorities have started to look deeper at the economic and financial needs that stablecoins seek to satisfy and at how to fill these needs, possibly with CBDCs (see “what are the advantages to a CBDC?”). For example, in September 2019, the finance ministers of France and Germany issued a joint statement, in which they criticised the plans for Libra and called on the ECB to examine the scope for issuing digital currencies.

4-Is a CBDC necessarily on a blockchain or using the Distributed Ledger Technology?

No, CBDCs need not rely on the DLT (Distributed Ledger Technology) and even less so on the specific blockchain technology (which is a type of DLT). The first reason is that other available, more traditional technologies can be more efficient. For retail CBDCs, this is particularly clear as an account-based version, for example, could be a simple replication of current commercial banking technologies, with the central bank offering deposit services directly to the public. This would be a way to avoid the very high computing burden necessary to validate transactions in some fully decentralised DLT like the blockchain used for Bitcoin (this is also known as the “scalability problem”)¹¹.

¹¹ The need for a consensus to emerge on the large network, with increasingly burdensome “proof of work”, means that only a handful of transactions can be recorded each second on Bitcoin: <https://www.blockchain.com/en/charts/transactions-per-second>

It is also worth keeping in mind that although the DLT is often seen as fully decentralised by nature (the choice made for Bitcoin), it need not be so. For example, the Swedish Riksbank's e-krona project¹² is based on a tiered DLT architecture (see chart 2): the nodes in the network (where transactions and balances are kept and synchronized) will be limited and each participant in charge of a node will need to be approved by the Riksbank. The node owners will serve as intermediaries between the Riksbank and the public.

A second reason is that available technologies are evolving with large R&D efforts in this field. For wholesale CBDCs (i.e. token-based) for example, a blockchain appears as the most likely technology platform, but other technologies may support digital tokens in the future.

5- Is CBDC issuance likely in the near term?

Although it is receiving a lot of interest and is now widely studied, actual CBDC issuance is rather unlikely in the very short-term, beyond tests already in progress (in Sweden and in China in particular).

Indeed, several obstacles will need to be overcome:

- The technology needs to be tested for its scalability, resilience...
- Legal hurdles exist in several countries, effectively prohibiting the central bank to issue a retail CBDC. These hurdles will need to be lifted by parliaments.
- The impacts of a retail CBDC are potentially huge (on banks and credit, on financial markets, on monetary policy: see below) and difficult to apprehend *ex ante*. Comprehensive testing and numerous simulations are needed.
- In the end, a democratic debate would need to occur on the ambition and scope of the CBDC, especially whether the aim is just to provide a basic alternative to cash, or to bank deposits as well. Another debate would be on the degree of privacy and anonymity and how it is supervised. Inclusiveness (ease of use for vulnerable persons for example) is another major aspect.

Beyond a 1-2-year horizon, however, CBDC issuance may well be observed, probably starting with wholesale CBDCs. Regarding retail CBDCs, China and Sweden are among the most advanced in the test phase. In China, a test is already running in four cities, but we have no details on its duration. In Sweden, the e-krona test is set to last at least until February 2021, with an option for extension for 7 years. Given that tenders for technological infrastructure, legal amendments etc. would need to be

¹² A retail CBDC, whose testing phase was started in February 2020: See the [Riksbank website](#)

organized if the country decides to issue an e-krona, it seems difficult to envision a launch before several years.

Key CBDC projects (non-exhaustive list)

Country	CBDC	Project	Comments
Canada	Wholesale	Test (Project Jasper) launched in March 2016	Partnership between the Bank of Canada, Payments Canada and private financial institutions, for payments on a DLT. Research and studies still ongoing.
Canada	Retail	Contingency planning (February 2020)	The Bank of Canada is making contingency preparations to be able to issue a retail CBDC in a short timeframe, if it (and a future Government) decides so. Two scenarios may lead to this decision: broad disappearance of banknotes in payments or large adoption by Canadians of a private digital currency.
China	Retail (DCEP)	Test, ongoing	Research started in 2014 and a test is in process in 4 cities. The architecture is tiered, as financial intermediaries distribute the DCEPs created by the central bank to wallet holders. Peer-to-peer and offline payments seem possible. Not clear if DLT is used. Reason for interest: disappearance of cash and duopoly of private e-payment providers
France	Wholesale	Test launched in May 2020	8 projects from private institutions were selected in July 2020; first test done in May with Société Générale Forge. Reason for interest: Improving efficiency of interbank market and market funding of the economy; contributing to Eurosystem research on CBDCs.
UK	Retail	Consultation started March 2020	Discussion paper published in March 2020. Reason for interest: problems linked with disappearance of cash, defence against private stablecoins
UK	Wholesale	Consultation TBA	
Uruguay	Retail (e-peso)	Test ended in April 2018	6-month test in real conditions, with limited issuance. Token based. Wallets on mobile phones, with P2P and P2B payments, anonymous but traceable. Reason for interest in CBDC: increase financial inclusion

Singapore	Wholesale	Test (Project Ubin). Phase 1 launched Nov 2016. Phase 5 nearly over.	Project in 5 phases, on a DLT in partnership with R3 and financial institutions. Phase 1: Digital tokenization of SGD; Phase 2 (2017): Domestic interbank transfer (3 DLT platforms tested); Phase 3 (2018): Delivery vs. Payment for settlement of tokenized assets; Phase 4 (2019): Cross border payment in CBDC (with Bank of Canada); Phase 5 (2019, ongoing): Blockchain network able to connect to other blockchain network and handle different currencies.
Sweden	Retail (e-krona)	Test launched in February 2020	Test expected to end in February 2021. Conducted with a private consulting firm, on the CORDA (R3) platform (a “permissioned DLT”). Reason for interest in CBDC: problems linked with disappearance of cash

Sources: SG Economics & Sector Studies, Central Banks, BIS

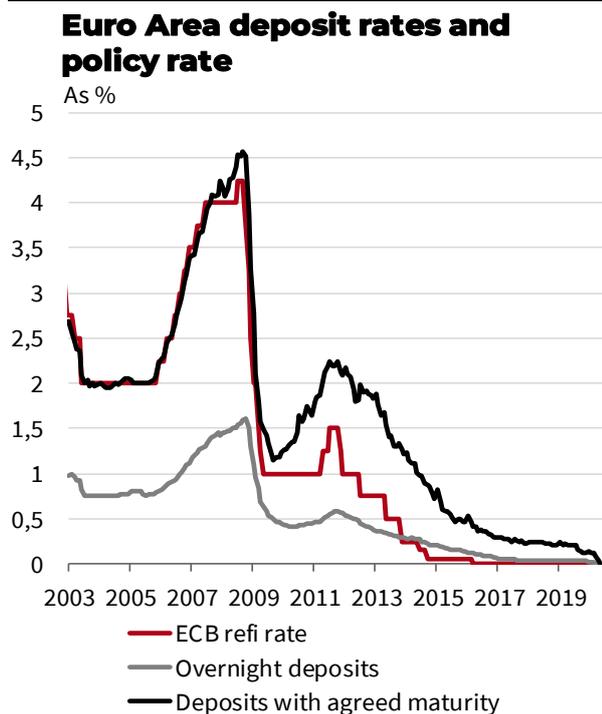
6-What would be the impact on monetary policy?

The issuance of a retail CBDC could significantly change the way monetary policy is conducted and the channels through which it affects the economy, depending on key design choices for this retail CBDC, and on its adoption. On the other hand, wholesale CBDCs do not seem to be likely game changers on this front, if they are restricted to counterparties already benefitting from an access to central bank deposits and liquidity.

A widely-used and interest-paying retail CBDC may improve the pass-through of policy rate changes to the real economy. Indeed, if the interest on this CBDC is linked and close to policy rates, then deposit rates at commercial banks would need to adjust quickly to avoid large swings in deposit amounts.

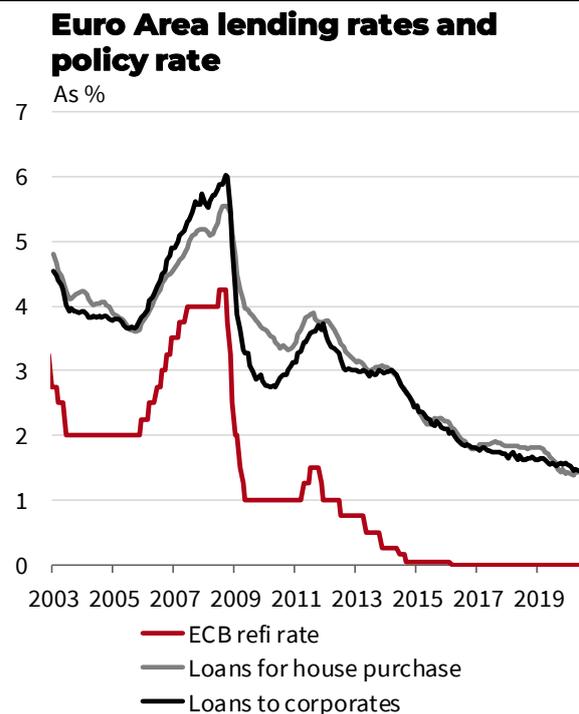
However, in most advanced countries, monetary policy pass-through is generally considered to be good and not in need of reinforcing (see chart below). In addition, bank deposits are part of a larger offer of banking services. Their remuneration may thus be difficult to disentangle from the prices of these other services (BIS, 2018), barring a large shift away from universal banking to a fragmentation of financial service providers.

Chart 5: Pass-through of policy rates to deposit rates is already strong even in the Euro Area



Sources: ECB, SG Economics & Sector Studies

Chart 6: Pass-through to lending rates could be weakened if bank deposits leak to a CBDC



Sources: ECB, SG Economics & Sector Studies

Box 2: The unique case of the euro area regarding retail CBDC impacts

Several factors are specific to the Euro Area when considering likely implications for retail CBDC issuance.

First, monetary policy is common but banking markets remain national, not least because of government policies (e.g. fiscally advantageous savings accounts like Livret A in France). This is also due to the unfinished Banking Union and in particular the still missing European Deposit Insurance Scheme. As such, any positive impact of a CBDC on monetary policy pass-through would depend on governments adapting quickly national schemes. Otherwise, large flows from some national banks to the Eurosystem (the issuer of the CBDC) may occur, with potentially destabilizing impacts.

Another key specificity relates to redenomination risks within the Euro Area. Should the CBDC be issued by national central banks? In this case, fears of redenomination as witnessed during the Euro Area crisis may lead to withdrawals from weak countries' CBDCs, highlighting even more explicitly the country's fragility. Should the CBDC be issued or at least backed by the ECB, then? This would certainly be a key assurance for CBDC depositors from weak countries in times of crisis, at the price of even larger TARGET2 imbalances (TARGET2 balances represent the net position of a

country's central bank to the rest of the Eurosystem – it is already very negative for peripheral countries and very positive for Germany¹³).

Finally, a retail CBDC could also have specific positive effects on Euro Area banks: given that they currently hold very large excess reserves subject to negative rates, deposit withdrawal would reduce excess reserves and thus the bill from these negative rates. This would likely not to be welcomed by banks, however, as reserves are an important part of their HQLA requirements whereas there are other ways to cap the bill from negative rates on banks ([tiering](#), very advantageous refinancing operations...).

Second, interest-paying CBDCs could enable more deeply negative rates, provided they effectively replace cash. Indeed, applying the negative interest rate on the CBDC would leave nowhere else to go for savers as cash hoarding would no longer be available¹⁴. The “zero lower bound” may thus be more easily bypassed, notwithstanding other issues related to negative rates (on bank profitability, on confidence in money...) and risks of crossing a possible “reversal rate”.

On the other hand, transfers from bank deposits to CBDC would probably weaken the transmission of monetary policy through the bank lending channel. Indeed, if this transfer is massive, bank funding would rely more heavily on market sources and/or on central bank refinancing. The first is subject to sometimes volatile conditions, especially in economic downturns. The second encumbers bank assets because of collateral needs. Bank funding – and bank lending with it – may thus become more procyclical, especially if flight-to-CBDC phenomena appear during crises (see more below: “What would be the impact on banks’ business models and funding?”). In this respect, central banks would have to be even more proactive during crises, with easier collateral rules and support to bank funding markets (covered bonds and ABS purchases...).

In the end, the net impact on monetary policy effectiveness is unlikely to be very positive, while adding to implementation challenges. Bank-centric financial systems may be in a relatively worse position (see below). This would be particularly the case if the savings and lending markets are heavily tweaked by government interventions, as coordination problems with the central bank would be heightened.

¹³ Because deposits would flee from weak countries to CBDC on the ECB balance sheet, while local banks would need to increase borrowing from their central bank to compensate these outflows.

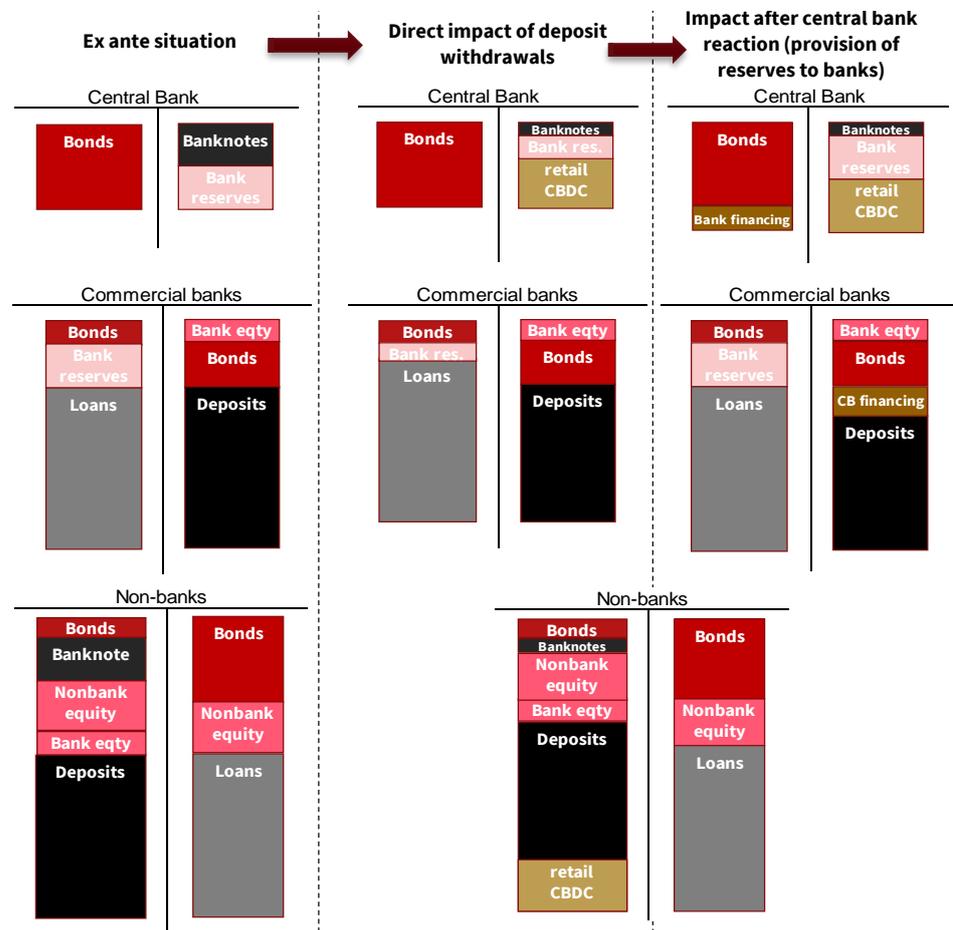
¹⁴ *Enabling Deep Negative Rates to Fight Recessions: A Guide* - Ruchir Agarwal, Miles Kimball - April 2019

Box 3: Balance sheet impacts of a retail CBDC

How would a retail CBDC affect balance sheets? We illustrate below a case where both banknotes and commercial bank deposits are exchanged for a new retail CBDC.

In a first, mechanical step, this leads to a change in the composition of central bank liabilities and of non-banks assets. Commercial bank assets and liabilities decrease: they have less deposits (liabilities) and they order the central bank to debit a corresponding amount from their reserves (assets) which are then credited to the non-banks' CBDC account.

In a second step, we consider that bank reserves at the central bank are too low: the central bank must issue new reserves (through refinancing operations or open market operations): its balance sheet grows until the amount of bank reserves is considered enough again. In this step, the balance sheet of non-banks doesn't change.



In this ex ante situation, bank reserves are considered as just appropriate

Banknotes are converted to CBDC; deposit withdrawals drain bank reserves; banks' loan-to-deposit ratios change; bank balance sheets decrease in size

The Central Bank provides banks with new reserves, inflating its balance sheet; Banks' funding mix has changed

7- What would the impact on banks' business models and funding be?

We find that a *retail* CBDC could be a game-changer and a challenge for banks, although not necessarily in the very short-term.

BANK FUNDING:

In normal times (no financial crisis), banks would face a negative shock on their deposit base¹⁵, as depositors would change part of their bank accounts into the retail CBDC. The size of this shock would obviously depend on the relative attractiveness of the CBDC. **In particular, the interest rate spread between the CBDC and checking accounts would be a key factor to watch and could of course be adjusted by the central bank to limit disruptions on bank deposits.** Additional functionalities offered, fiscal incentives etc. would also factor in the size of bank deposit withdrawals. Interest rates on deposits may have to increase, all else being equal (see section on monetary policy).

This loss in stable funding would have to be compensated, via two channels: market funding and/or central bank funding. These alternatives are, of course, costlier and/or more susceptible of generating asset encumbrance (due to collateralisation needs). In jurisdictions subject to Basel III rules, liquidity ratios such as the Net Stable Funding Ratio (NSFR) would become even more binding. In the short term, loan-to-deposit ratios may rise again, constraining credit supply.¹⁶

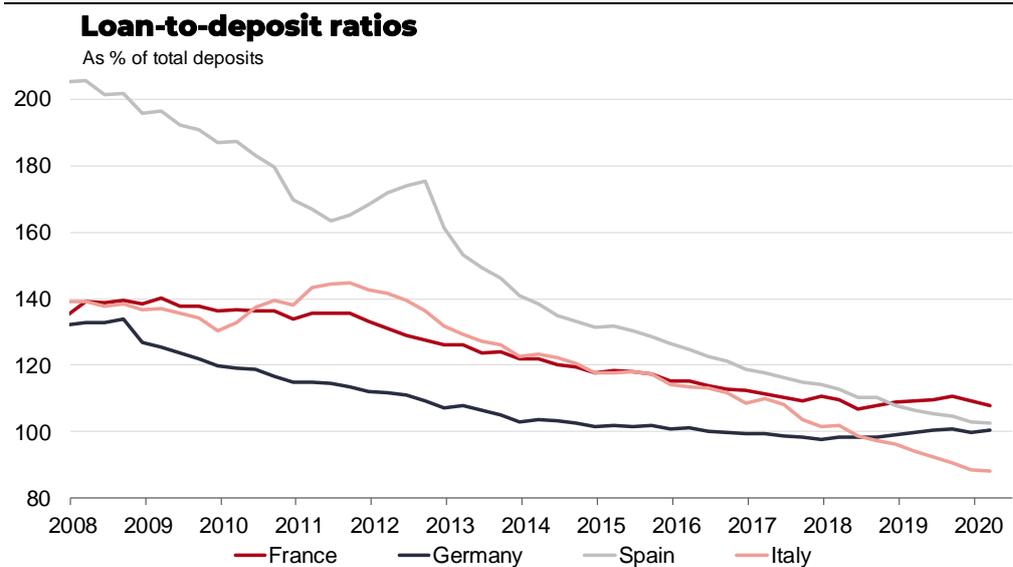
Given these impacts, shifts in lending patterns may also appear. Indeed, the larger reliance on central bank funding (against collateral) or on securitisations and covered bonds would incentivize banks to prioritize collateralizable credit claims. This would likely support real estate financing and demand for this type of asset, at the expense of short-term corporate credit and investment in intangibles. In this context, a fear is that second-round effects on real estate prices and banks' risk taking appear.¹⁷

¹⁵ Because demand for CBDC would likely be larger than for banknotes given its improved usefulness for daily life

¹⁶ Brunnermeier and Niepelt (2019) show that the impact on credit could be zero, but under very specific conditions, especially that the central bank doesn't require collateral against bank funding and lends on the same terms as former depositors did.

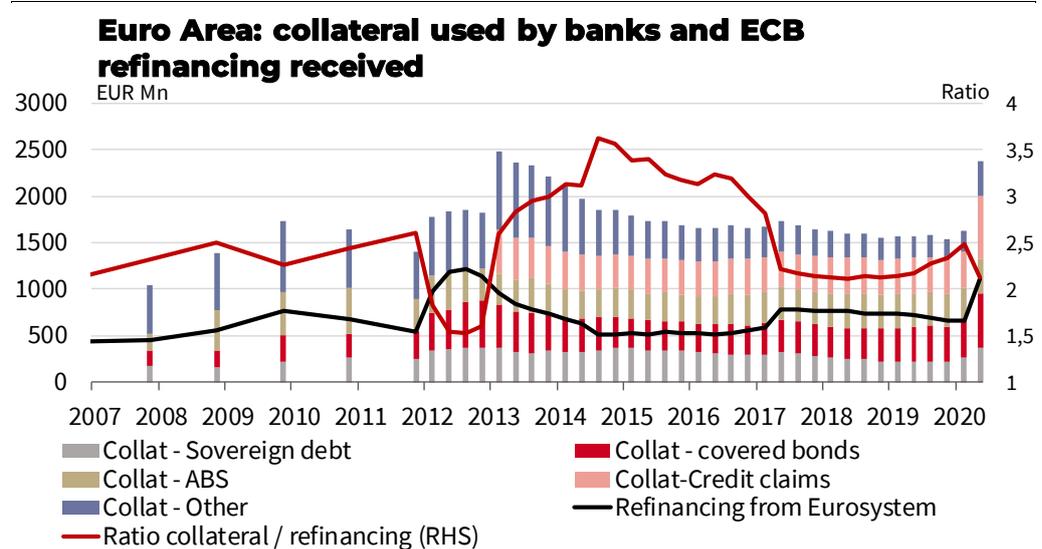
¹⁷ Fougère, D., Lecat, R. and Ray, S. (2019), and Dell'Arricia G., Kadyrzhanova D., Miniou C., Ratnovsky L. (2020)

Chart 7: Basel III regulations (NSFR in particular) have strengthened the need for banks to attract deposits*



* The implementation of the NSFR has in effect led to a convergence of loan-to-deposit ratios to 100 as it encourages deposit taking and discourages short-term market funding. A retail CBDC could tend to unwind this trend.
Sources: ECB, SG Economics & Sector Studies

Chart 8: The ECB already had to ease collateral rules, accepting credit claims, to ensure banks have access to its lending facilities



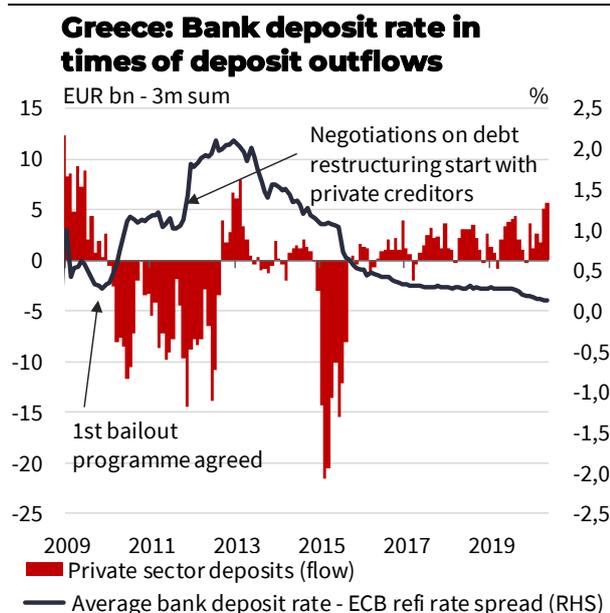
Sources: ECB, SG Economics & Sector Studies

In stressed times like banking crises, the negative shock on bank deposits is very likely to be much larger. Indeed, in the face of higher credit and liquidity risks on bank deposits, depositors could switch *en masse* to CBDC, as this swap would be nearly frictionless and costless (more so than for banknotes). The rise in deposit rates necessary to limit this *flight-to-CBDC* would only exacerbate liquidity and

profitability issues for banks. In this situation, the central bank would have only three solutions:

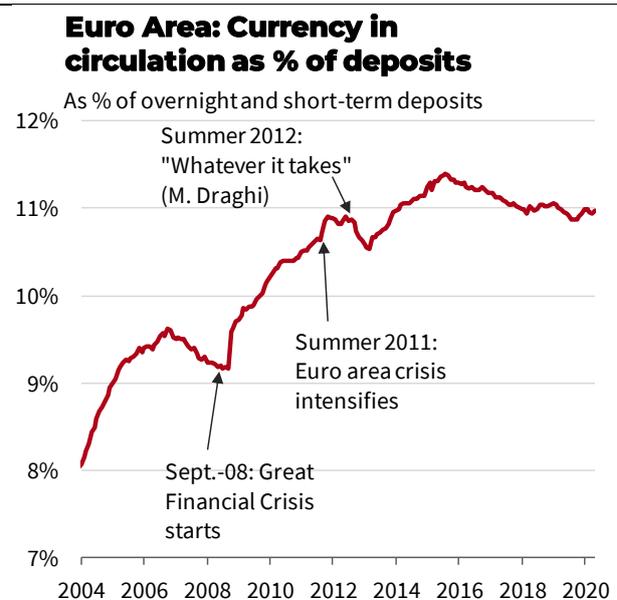
- Extend its refinancing operations to banks, for amounts probably significantly higher than in previous occurrences of bank runs. The problem of collateral availability would thus become even more acute.
- Implement hard caps on CBDC deposits.¹⁸ Such a move could however lead to the appearance of an informal exchange rate between CBDC deposits and commercial banks deposits.
- An alternative solution would be a tiered remuneration of the CBDC, with possibly deep negative rates on CBDC amounts above a given threshold¹⁹. While interesting and usable for moderate stress periods, the efficiency of this tool would likely fall short during severe crises, not least because of the political cost of applying deeply negative interest rates.

Chart 9: Taming deposit flight with higher rates can be costly and unsuccessful for banks



Sources: Bank of Greece, SG Economics & Sector Studies

Chart 10: Flight from deposits to cash takes time to reverse – it would be worse with a CBDC



Sources: ECB, SG Economics & Sector Studies

BANK BUSINESS MODELS:

The impact of retail CBDC issuance could be very large on bank business models too, if the characteristics and remuneration of the CBDC prove very attractive.

¹⁸ This may in turn confirm Gresham’s law (« bad money drives out good »): in extreme cases, CBDC could be hoarded and only payments in private money would remain. The CBDC would thus fail one of its main raison-d’être: payments resilience.

¹⁹ See for example “Tiered CBDC and the financial system”, U. Bindseil, ECB WP N°2351, January 2020

A first channel would be decreased revenues from maturity transformation if the interest rate on the CBDC is set too close to policy rates. Indeed, the loss of retail deposits would force banks to rely on more volatile and expensive funding (see above). Assuming banks are able to cover these costs through higher lending rates, lending volumes would still be lower in consequence. In some banking systems, the competitive landscape or administrative constraints may limit this pass-through to lending rates, hampering further bank profitability.

The marketing and pricing of retail banking services may also need to change. Currently, cross-subsidisation between product can occur when banks consider the customer relationship as a whole. Already the increasing competition of FinTechs and new payment services allows customers to diversify the purchase of financial services and split their budget in this category, putting into competition several providers on any given service. This trend has the capacity to lead to a commoditization of banking services, which would be conducive of decreasing margins. In this respect, the issuance of a retail CBDC, with its standardized architecture open to new non-bank players, may well accelerate this transformation.

8-What would be the impact on financial markets?

Focusing first on a retail CBDC, we find that the introduction of the latter in an economy is far from neutral for financial markets. This impact would play through two main channels:

- **Larger collateral needs:** the higher bank recourse to central bank refinancing operations, to compensate lost deposits, would increase collateral needs. Demand for financial assets accepted as collateral by the central bank would thus increase: typically highly-rated bonds and securitisations. Hoarding of these assets in times of financial market stress may also increase while the procyclicality of rating downgrades on the amount of collateralizable assets would increase (as securities used as collateral are usually marked-to-market). In addition, bank loans directly accepted by the central bank would also be supported (see part on bank funding and business models). In the end, changes in central bank collateral policies would have even larger impacts on financial markets and the relative prices of assets²⁰.
- **Larger central bank footprint on financial markets.** Central banks providing additional reserves to commercial banks through Open Market Operations (like the Federal Reserve) would gain further prominence on financial markets.

²⁰ See for example: “Violating the law of one price: the role of non-conventional monetary policy” – Corradin & Rodriguez-Moreno <https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1927.en.pdf>

Flexible central bank operations, with efficient and affordable securities lending mechanisms, would be key to preserve liquidity in financial markets.

A wholesale CBDC, on the other hand, could prove positive for financial markets: efficiency gains on financial transactions, especially for settlement and post-trade operations, would decrease transaction costs and enhance liquidity. A precondition would be that the CBDC is combined with the tokenization of assets. The very strong network effects at play would likely be a huge boost for the international use of the first G10 currency to be made available as a wholesale CBDC. A successful wholesale CBDC could also provide the common technological playground needed to support and harmonise the transformation and technological efforts of financial institutions, Fintechs etc.

However, as underlined by the Canadian Project Jasper, a large adoption of the CBDC (across markets and across the post-trade/settlement process) would be needed to realize efficiency gains, as partial adoption would leave back-office needs intact. Some potentially destabilizing aspects may also appear with the emergence of smart contracts linked with the CBDC, not least due to the diminishing need for third parties in transactions.

9-Is CBDC issuance aligned with Climate goals?

When thinking about the carbon footprint of a CBDC, it is tempting to look at cryptocurrencies (and Bitcoin in particular) for comparison purposes. This comparison is very far from ideal, as CBDCs and Bitcoin are likely to rely on different technologies, not least due to various central banks' commitments on their carbon footprints. Looking at the Bitcoin carbon impact remains interesting, as a baseline to compare to new and future protocols.

Stoll, Klaassen and Gellersdörfer (2019)²¹ estimate the annual carbon footprint of Bitcoin mining, based on data as of November 2018, to range between 23.6 to 28.8MtCO₂. This represents the annual CO₂ emissions of Sri Lanka to Bahrein²², despite the modest use of Bitcoin relative to global payments (and an approximate market cap of EUR180bn at the time). This large footprint is the result of the extensive computing needs built into the Bitcoin's blockchain architecture²³. It also

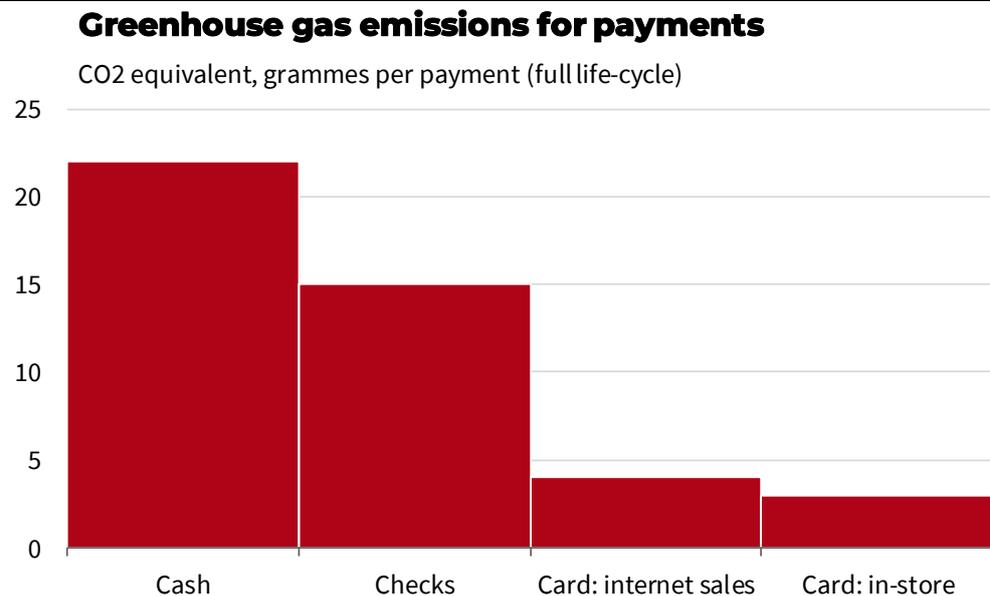
²¹ *The Carbon Footprint of Bitcoin – Stoll, Klaassen, Gellersdörfer, Ulrich. (2019). SSRN Electronic Journal. 10.2139/ssrn.3335781.*

²² *CO₂ emissions from fuel combustions only, 2017, source IEA*

²³ *Because transactions are validated by consensus and to make this consensus nearly-impossible to manipulate, validators must provide a “proof of work”: solving a cryptographic puzzle using brute computing force. As in addition any Bitcoin user can participate in this validation process (which is remunerated, because the more “miners” there is, the harder the consensus is to manipulate) there is always a large computing power tasked to solve the same cryptographic puzzle.*

results from the location of Bitcoin miners (mostly in countries with more carbon-intensive electricity generation).

Chart 11: Card payments emit little greenhouse gases



Sources: French Banking Federation, EY, SG Economics & Sector Studies

This compares quite unfavorably with traditional payments: In 2011, the French Banking Federation and EY²⁴ estimated that greenhouse gas emissions from retail payments in France, including the full life-cycle of different supports, was about 0.01% of the French carbon footprint. This represents approximately 0.05MtCO₂e, for an economy close to EUR2.5tn in terms of GDP.

A CBDC is different from current retail payments but also from the Bitcoin, as pointed above. Hence, its carbon footprint remains very uncertain and this is even more the case for wholesale CBDCs whose productivity-enhancing features could be key.

In the end, this impact will largely depend on four key factors:

- **Infrastructure choice:** the kind of DLT and its consensus mechanism (whether open to anyone or limited to permissioned participants, whether requiring an energy-intensive proof of work or another mechanism) will be key factors in the carbon intensity of the CBDC²⁵. The growing use of DLTs not based on proof of work consensus (the Swedish e-krona uses a simplified consensus for example) is a reassuring sign for the carbon footprint of future CBDCs.

²⁴ *Empreinte environnementale des moyens de paiement – Fédération Bancaire Française, EY, Juin 2011*

²⁵ For more details, see for example Sedlmeir, J., Buhl, H.U., Fridgen, G. et al. [The Energy Consumption of Blockchain Technology: Beyond Myth](#). *Bus Inf Syst Eng* (2020).

- **Which kind of payments are displaced:** as cash is the most CO2 intensive of the current payment technologies, a CBDC merely replacing cash may help decrease a country's carbon footprint. On the other hand, displacing card payments may increase carbon emissions.
- **National electricity mix:** CO2 emissions from CBDC usage will obviously depend on the electricity mix of the country. An option for countries issuing a CBDC while relying on carbon-intensive electricity generation may be to delocalise its computing capacities dedicated to CBDC. This, however, poses key questions regarding sovereignty and privacy.
- **Efficiency gains:** A positive impact from a CBDC (notably wholesale) may arise if the latter generates large efficiency gains in payment or settlement processes, together with the tokenization of assets. Example are numerous, while very complex to model: multiple reconciliations between many market participants vs. unique trade repository on-chain, duplicate calculation of the same coupons amount at different levels vs. unique coupon reference calculated by a common smart contract, etc ...

10- What are the operational risks to a CBDC?

The range of operational risks potentially stemming from CBDC issuance are a final, major hurdle for CBDCs, and particularly retail CBDCs. They relate to cybersecurity, to integrity, to money laundering or to terrorism financing. At stake is the central bank's reputation, its most important asset to conduct monetary and foreign exchange policies.

Cybersecurity risks would take increasing importance for the central bank, as banknotes are replaced by CBDC wallets. Not only would the likeliness of an attack increase for the central bank, but the amounts at stake would also jump given the ease to transfer large amounts electronically. Two key aspects on this front are:

- **Systemic resilience:** A number of central banks considering CBDC issuance (the Riksbank in particular) expect that a CBDC would improve resilience in the most extreme situations, compared to private payment systems. In this goal, CBDC would need to be as resistant as possible to DDoS attacks, and have basic services available even during power or internet outages. A CBDC aspiring to an international use would likely need to be especially resistant to such cyber attacks.
- **Data theft / identity theft...:** Depending on the infrastructure technology, risks to the privacy of users, or the integrity of their accounts, can be important. Collection of personal data, in line with Know-Your-Customer (KYC) and Anti-Money-Laundering (AML) regulations, would need to remain limited to

minimize risks. Integration on devices such as smartphones may also increase risks (Minwalla, 2020).

Integrity risks would also increase markedly with a CBDC, as the latter may allow for double-spending, whereas banknotes are “only” subject to counterfeiting risks. Integrity is key to maintain as it is a prerequisite for confidence in money, under all its forms. For example, a CBDC based on DLT infrastructures could see double-spending if a malicious actor were to control a majority of the nodes. Double-spending could also occur if offline storage devices were hacked.

Finally, KYC and AML regulations would affect the issuing central bank more forcefully, as the latter would provide access to the financial system directly to households and firms. Tight oversight of these issues is essential for the central bank credibility and for the acceptability of the CBDC internationally. Still, there are ways to minimize the burden for central bank, for example using a tiered system whereby private actors oversee relations with the public (as in the e-krona pilot).

In the end, the design of the CBDC is set to be the first and most important line of defence regarding these risks. However, large resources will still be needed to monitor cyber risks, the integrity of money, etc. In this respect, the size of the economy is likely to matter as fixed costs to CBDC issuance will be large.

Hence, international cooperation would be essential for the security of international payments as well as to support smaller countries. Absent such cooperation, small emerging countries issuing a CBDC may see their cyber security risks increase markedly, and cases like the 2016 Bangladeshi central bank “cyber-heist” become more frequent.

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