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Central bank digital currency - financial system implications and control

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IT progress and its application to the financial industry have inspired central banks and academics to reflect about the merits of central bank digital currencies (CBDC) accessible to the broad public. This paper first briefly recalls the advantages that have been associated with CBDC and reviews some relevant background from the history of the issuance of different forms of central bank money. It then discusses two key arguments against CBDC, namely (i) risk of structural disintermediation of banks and centralization of the credit allocation process within the central bank and (ii) risk of facilitation systemic runs on banks in crisis situations. The paper proposes as solution a two-tier remuneration of CBDC, as a tested and simple tool to control the quantity of CBDC both in normal and crisis times. It compares this solution with the one of Kumhof and Noone (2018). It is however also acknowledged that controlling the quantity of CBDC is not necessarily sufficient to control its impact on the financial system. Finally, the paper compares the financial account implications of CBDC with the one of crypto assets, stable coins, and narrow bank digital money, noting the similarity and differences in terms of implications on the financial system. It is concluded that well-controlled CBDC seems feasible, without this implying that CBDC would not catalyze change in the financial system.

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1. Introduction

Both academics and central banks have recently started to analyze merits and dangers of introducing central bank digital currencies (CBDC), i.e. some form of central bank money handled through electronic means and accessible to the broad public¹. CBDC could therefore be considered a third form of base money, next to (i) overnight deposits with the central bank, currently available only to banks, specific non-bank financial firms, and some official sector depositors; (ii) banknotes, being universally accessible but arguably of limited efficiency and relying on old technology. Some publications distinguish the case of “wholesale” and “general purpose” CBDC, the former being only accessible to certain firms, while the latter universally accessible to all households. This paper discusses general purpose CBDC, since wholesale CBDC is of more limited scope and does not really question the established structure of the monetary base. General purpose CBDC could be implemented in **two alternative technical formats**:

- (1) CBDC could be offered in the form of **deposit accounts with the central bank** to all households and corporates. From a technological perspective, this would not be very innovative, but just a matter of scaling the number of deposit accounts currently offered. Although scaling is not innovative per se, it may be technologically challenging. For example, in the case of the Eurosystem, the number of accounts could grow from around 10,000 to some number between 300 and 500 million (all registered major inhabitants of the euro area, plus firms fulfilling some legal status and/or some minimum criteria on payment or economic activity). The actual servicing and technical maintenance of the accounts could be assigned to one or several third-party providers, to ensure efficiency and to avoid that the (presumably somewhat less efficient) public sector takes over more tasks than needed. The accounts could offer the usual access- and payment functionality of sight deposit accounts with banks, including internet- and app-based solutions. Commercial banks would provide the service to exchange bank deposits against CBDC and banknotes, charging a competitive fee (similarly to ATM fees today).
- (2) Alternatively, the central bank could offer a **digital token currency** that would circulate in a decentralized way without central ledger. This is often associated with anonymity, i.e. meaning that the central bank would not know who currently holds the issued tokens (like in the case of banknotes).

Deposit based CBDC seems simpler and can obviously be made effective against money laundering and other illicit uses (Berentsen and Schär, 2018). It also seems to allow for a high security and control of the circulating amount of CBDC base money, without this requiring complex and/or computationally intensive solutions². One might argue that if banknotes would no longer be generally accepted in retail payments (assume that neither consumers nor retailers would want to continue using banknotes), a token CBDC could be nice to have as it could allow to preserve anonymous payments (e.g. Häring, 2018, strongly advocates the anonymity of payments). However, others will find the arguments for anonymous payments with token money more difficult to understand, or will argue that a more proportionate solution would consist in a sufficient protection of electronic payments data.

A number of quite diverse **benefits of CBDC** have been put forward in the literature, as summarized in table 1 (see also e.g. Engert and Fung, 2017; Mancini-Griffoli et al, 2018)). The table also explains (in the

¹ Recent publications include Engert and Fung (2017), CPMI-MC (2018), Kumhof and Noone (2018), Sveriges Riksbank (2018), Armerlius et al (2018), Juks (2018), Nessen et al (2018) – see also the further literature referenced there. According to the survey of Barontini and Holden (2019, 7), 70% of responding central banks are currently engaged in CBDC work. Five central banks would be progressing on, or running pilot projects (p. 8).

² Of course, it is not excluded that effective solutions preventing money laundering and other illicit activities and a high security and control of the circulating amount of CBDC can be achieved with a token CBDC. However, as also convincingly argued by Berentsen and Schär (2018), a deposit based CBDC offers simpler solutions to all of these issues.

last column) under what possible further conditions the respective advantage would actually materialize, or be particularly strong. Most of the proposed advantages are subject to controversial debate in the literature.

Table 1: Overview of benefits that some have associated with CBDC, and related factors or requirements

Benefit of CBDC	Possible further factors or requirements
A. Efficient retail payments-	
A.1 Making available efficient, secure and modern central bank money to everyone	In particular in economies without high-quality electronic commercial bank money, and/or without a secure and efficient payment system
A.2 Strengthening the resilience, availability and contestability of retail payments	In particular in economies in which banknote demand vanishes and private electronic payments solutions lack competition
B. Overcome use of banknotes for illicit payment and store of value	
B. Better control of illicit payment and saving activities, money laundering, and terrorist financing	Requires (i) discontinuation of banknotes (or at least of larger denominations); (ii) CBDC to not take the form of anonymous token money
C. Strengthen monetary policy	
C.1 Allows overcoming the ZLB as negative interest rates can be applied to CBDC	Requires discontinuation of banknotes (or at least of larger denominations)
C.2 Interest rates on CBDC provide for additional monetary policy instruments, independently of ZLB	
C.3 Easier ability to provide helicopter money	Requires that each citizen has a CBDC account
D. Sovereign money related	
D.1 Improve financial stability and reduce moral hazard of banks by downscaling the role of the banking system in money creation	CBDC takes over to large or full extent sight deposit issuance by banks
D.2 Larger seignorage income to state (and citizens) as state takes back money creation from banks.	CBDC takes over to large or full extent sight deposit issuance by banks

Consider these possible arguments in favor of CBDC in more detail below.

A. Efficient retail payments

CBDC offers a number of advantages with regards to the convenience, efficiency, stability and accessibility of retail payment. While electronic payments with all their efficiency gains have been possible for some decades on the basis of commercial bank money, offering electronic payments directly in central bank money could have additional advantages. A comprehensive analysis of these justifications of CBDC can be found for example in Sveriges Riksbank's (2018) second report on the e-krona project.

In short, collapsing demand for cash in the absence of CBDC would imply that citizens would no longer have access to the central bank balance sheet. In that state of the world, trust in the currency would entirely depend on trust in financial intermediaries issuing and managing commercial money. The Riksbank concludes on the basis of its report that the "proposed focus of this programme should be on developing an e-krona that constitutes a prepaid value (electronic money) without interest and with traceable transactions". Barontini and Holden (2019, 3-4) also report about a recently conducted pilot by the Central Bank of Uruguay, which would qualify as the most advanced and concrete CBDC experiment up to now, and which was part of a financial inclusion program.

A number of arguments can thus be distinguished that strengthen the case of CBDC to support efficient retail payments: (i) vanishing demand for banknotes; (ii) unsatisfactory access of relevant shares of

households to commercial banking system, which can occur both in least-developed countries (with a generally underdeveloped banking system) and countries with a relatively high income disparity, such as the US (see Rogoff, 2016); (iii) an unstable or overly concentrated retail payment infrastructure. The CBDC survey amongst central banks of Barontini and Holden (2019, 8) reports that for central banks, the four most popular reasons to consider CBDC are, in this order of importance, (1) payment safety; (2) payment efficiency; (3) financial stability and (4) financial inclusion. Only financial stability seems to fall out of the category A of arguments in favor of CBDC.

B. Prevent illicit payment and store of value with central bank money

This argument, which assumes a discontinuation or at least strong reduction in the role of banknotes, is developed in most detail by e.g. Rogoff (2016). Obviously, this motivation of CBDC would not apply if CBDC circulate as *anonymous* token money even for high amounts. Some, like Häring (2018), who are strongly pre-occupied with the privacy of payments and fear that internet retailers and state authorities use payments data to eventually curb the freedom of citizens, will not agree with this specific argument for CBDC.

C.1 Allows overcoming the ZLB as one may impose negative interest rates on CBDC

For example, Dyson and Hodgson (2016) argue that “if digital cash is used to completely replace physical cash, this could allow interest rates to be pushed below the zero-lower bound.” Rogoff (2016) develops this argument in detail. By allowing to overcome the zero-lower bound (“ZLB”) and therefore freeing negative interest rate policies (“NIRP”) of its current constraints, a world with *only* digital central bank money would allow for – according to this view - strong monetary stimulus in a sharp recession and/or financial crisis. This could not only avoid recession, unemployment, and/or deflation but also the need to take recourse to non-standard monetary policy measures which have more negative side effects than NIRP. Opponents of NIRP will obviously dislike this argument in favor of CBDC, and will thus see CBDC potentially as an instrument to overcome previous limitations of “financial repression” and “expropriation” of the saver.

C.2 Interest on CBDC provides an additional monetary policy instrument

Dyson and Hodgson (2016) consider that CBDC “widens the range of options for monetary policy: Implementing digital cash can allow new monetary policy tools to be used”. According to this view, varying interest rates of CBDC would provide for a new, non-redundant monetary policy instrument that would allow improving the overall effectiveness of monetary policy. This idea is developed further by Barrdear and Kumhof (2016, 3) who find that “a CBDC regime can contribute to the stabilization of the business cycle, by giving policymakers access to a second policy instrument that controls either the quantity or the price of CBDC in a countercyclical fashion. This second policy instrument becomes especially effective in response to shocks to private money demand and private money creation...” Meaning et al (2017) also analyse how CBDC could enrich the monetary policy toolkit and how it would impact the transmission mechanism, and come to the conclusion that it would all depend on the details of the design of CBDC. Finally, Berentsen and Schär (2018, 102) argue that interest on CBDC would simplify monetary policy as the “central bank would simply use the interest rate paid on these accounts as its main policy tool”. Mancini-Griffoli et al. (2018, 25) take the view that CBDC is unlikely to affect the main channels of monetary policy transmission, which is also the assumption taken here.

C.3 Easier ability to provide helicopter money

Again, Dyson and Hodgson (2016) argue that “digital cash can be used as a tool to increase aggregate demand by making ‘helicopter drops’ of newly created digital cash to all citizens, making it easier to meet the Bank of England’s monetary policy target of price stability.” Obviously, the relevance of this

argument will only be shared by supporters of helicopter money. Moreover, it could be argued that it is a relatively weak argument as it only *facilitates* the distribution of helicopter money (but is no pre-condition).

D.1 Improve financial stability and reduce moral hazard by downscaling banks

The arguments D1 and D2 in favor of CBDC relate to the vision that CBDC is a tool to make feasible the “sovereign money” idea, i.e. a monetary system in which banks would no longer “create” sight deposits and thus means of payment (Benes and Kumhof, 2012, Häring, 2018, 214-223, Mayer and Huber, 2014). For example, Dyson and Hodgson (2016) consider that CBDC “can make the financial system safer: Allowing individuals, private sector companies, and non-bank financial institutions to settle directly in central bank money (rather than bank deposits) significantly reduces the concentration of liquidity and credit risk in payment systems. This in turn reduces the systemic importance of large banks and thereby reduces the negative externalities that the financial instability of banks has on society. In addition, by providing a genuinely risk-free alternative to bank deposits, a shift from bank deposits to digital cash reduces the need for government guarantees on deposits, eliminating a source of moral hazard from the financial system.” Already 20 years ago, Huber (1999, 5-6), one of the key German supporters of “sovereign money”, summarized the sovereign money proposal as follows:

“The sovereign money proposal says: Give the central bank unimpaired full control of the total money supply on the legal basis of a general prerogative of money creation. In other words, have the entire money base - cash as well as non-cash money - exclusively issued by the central bank. This implies the abolition of the banking sector’s capability to create non-cash money in the form of sight deposits. Today, there is a mixed money base made up of one kind of money created by the central bank and another kind of money (sight deposits) created by the banks. Sovereign money still implies a two-tier banking system, but it does not mean having a mixed money base any longer, instead, just one kind of money from a single source, easy to understand, to handle and to keep control of. Sovereign money does not necessitate particular changes of institutional and market structures. Simply, banks would be credit brokers and no longer be credit creators. They would lose today’s seignorage, the extra profit from the creation of non-cash money. Apart from that, the normal profitability of the banking business will remain untouched. Banks would be able without any restrictions to continue to carry out every kind of business they do now,”

D.2 Seignorage income redirected to state (and citizens)

For example, Dyson and Hodgson argue that CBDC “can recapture a portion of seignorage and address the decline of physical cash...” Also e.g. Mayer and Huber (2014) give much prominence to the assumed fiscal advantages of sovereign money. They estimate that e.g. in the euro area annual additional state revenues would be in the order of magnitude of more than EUR 100 billion (assuming a pre-2008 interest rate level). Obviously, with the current low levels of interest rates, and the outlook on future interest rates as it is priced in yield curves, this argument has become rather irrelevant for the time being.

Overall, one may conclude from reviewing the arguments in favor of CBDC that the merits of CBDC of type A, i.e. contribute to an efficient, resilient, accessible and contestable payment system seem relatively uncontroversial, without this per se being sufficient to justify CBDC. Argument B is more controversial, but this controversy seems to be outside the area of payment system efficiency, monetary and financial stability. Argument C1 will be shared by monetary economists who support NIRP, but will be disliked by those who consider NIRP a form of financial repression. Arguments C2 and C3 are likely to be rejected by the majority of professional monetary economists. Finally, the sovereign money arguments (D) are also overall controversial, and again the majority of monetary economists are likely to reject them. Moreover, as will be discussed in sections 3 and 4, the disintermediation of the banking system has been considered as one of the major drawbacks and risks of CBDC.

Therefore, to isolate the more obvious, humble case for CBDC which is likely to be shared by most economists, namely that it could serve as an efficient retail mean of payment (Argument A) from the perceived danger that CBDC leads unintendedly to a sovereign money financial system (as it would boost so much the relative attractiveness of central bank money relative to bank deposits) **it seems essential to be able to steer the issuance of CBDC in such a way that it serves the efficiency of retail payments, without necessarily putting into question the monetary order by making CBDC a major form of store of value**³. It will be argued in this paper that such a steering is feasible, and with less fundamental change than inherent e.g. in the proposal of Kumhof and None (2018). The well-tested tool of tiered remuneration seems to be a way to ensure that the volume of CBDC will be well-controlled. A system of financial accounts calibrated towards the euro area will illustrate the mechanics and implications of CBDC and will allow presenting flow of funds implications.

The rest of this paper proceeds as follows. **Section 2** recalls some relevant history of the issuance of different forms of central bank money. **Section 3** discusses what some consider as the major problem with CBDC, namely that CBDC would disintermediate in a structural way the banking system (being what sovereign money advocates would consider a major improvement for the financial system and society). Section 3 also introduces the financial accounts framework that illustrates the impact of CBDC on the financial structure which will be used in different variants throughout the paper⁴. **Section 4** discusses the second danger associated with CBDC, namely that it would facilitate runs out of bank deposits into central bank money in financial crisis situations (i.e. not structural, but say “cyclical” disintermediation). Section 5 discusses the remedies that Kumhof and Noone (2018) have proposed to the two issues introduced in sections 3 and 4, being the so far most elaborate approach to dispel those concerns. Section 6 proposes an alternative, arguably simpler approach, in which the control of the quantity of CBDC is achieved through a tiered remuneration system. This would allow controlling the quantity of CBDC at a level such that the central bank balance sheet size could be kept broadly stable and significantly reduce the political constraints on controlling the quantity of CBDC through low or negative interest rates. Section 7 analyses to what extent controlling the quantity of CBDC would really imply at the same time neutrality of CBDC for the financial system. Section 8 compares CBDC to private digital money initiatives in terms of the impact on the financial system. **Section 9** concludes.

2. Lessons from the history of central bank monetary liabilities

Central banks have traditionally issued two main forms of liabilities: Deposits and banknotes. In addition, mixed forms such as certificates of deposits have been widely used in some places, such as in particular in Naples, where the “fede di credito” served as a means to pay with deposits, without having to be present in the public bank. As reviewed e.g. in Roberds and Velde (2014), Ugolini (2017), or Bindseil (2019), the first public banks issuing means of payment, i.e. the earliest central banks, did so in the form of deposits, and not in the form of banknotes. Before the Stockholm Banco invented modern banknotes in 1661, there had been at least six large and successful early public central banks that successfully issued giro deposits, namely: the Taula de Canvi founded of Barcelona in 1401, the Casa San Giorgio of Genoa of 1407, the Banco di Rialto of Venice of 1587, the Bank of Amsterdam of 1609, the Hamburger Bank of 1619 and the Banco del Giro of Venice in 1619. Moreover, the Naples public banking system created in

³ Armelius (et al.) also consider that the net macro-economic benefits of CBDC depend on the positive effects from a more efficient and resilient payment system, against the possible negative effects on credit provision and financial stability.

⁴ A financial accounts framework to analyse CBDC is also used by Meaning et al., (2017), but more in the form of a graphical illustration.

the 1580s also worked as a system of quasi-central banks with mutual recognition of their liabilities. These public banks granted the possibility to open deposit accounts in principle to anyone, partially subject to a minimum initial deposit. In this sense they granted universal access to central bank liabilities (such as banknotes do, and such as CBDC would). However, in the absence of electronic remote access, reach was limited to those who could come to the bank to undertake their transactions physically there, and who had some wealth to deposit and to use for payments (whereby the *fede di credito* solved this problem to some extent – see below). For example, the *Taula de Canvi* of Barcelona would have had 1460 depositors in the year 1433 (Roberds and Velde, 2014, 29). The Bank of Amsterdam had more than 2000 depositors between 1650 and 1790, with a peak close to 3000 in the first decades of the 18th century (Van Dillen, 1934). Actually, there was no discrimination at that time between “households”, “corporates” and “commercial banks” with regards to access to central bank accounts. Most depositors were domestic and international merchants and other wealthy businessmen and families, including some who specialized in financial intermediation services. Early central banks also already acted systematically as the bank of the government, i.e. receiving the deposits of the government, and providing the accounts of the government being used for receiving tax and other payments and for making large payments e.g. to suppliers.

Banknotes were a more universally accessible form of central bank liabilities as they were by definition transferable and “to the bearer”, i.e. everyone could receive them as means of payment, and could further use them to make payments to others. Banknotes were first issued by the *Riksbank* in 1661-64, and then again by the Bank of England (founded in 1694) and the Bank of Scotland (founded in 1695). The Bank of Scotland would have been the first central bank issuing *low-denomination* banknotes almost from the beginning, i.e. which were also suitable for retail payments and thereby effectively granting universal access to central bank money. According to Saville (1995, 26), the Bank of Scotland issued 5- and 10 Pounds Scot notes as of 1700, and in 1704 started to issue 1 Pound Scots notes (with 12 Pound Scot being equal to 1 Pound Sterling). The Bank of England began issuing notes with fixed denominations only in 1725, the first such denomination having been £20. In 1759, notes for £10 and £15 were issued. The war with Napoleon led to the issue of banknotes for £5 in 1793 (Bank of England, 1969, 212), corresponding to around 523 gram silver, i.e. still a very large value at that time.

An intermediate form of central bank liabilities were the so called *Fede di Credito* that were invented in the late 16th century by the Naples public banking system (see e.g. Costabile and Nappi, 2018). These were essentially certificates of deposits that could be used to settle financial claims in central bank deposit money without physical presence at the central bank. Payment via *Fede di Credito* may be considered an early form of today’s electronic payments via bank deposits – they relied on bank deposits and the associated booking in a central ledger, but payments could be done remotely. Of course, settlement modalities were different, as the transaction was only settled in the books of the public banks once a *Fede* returned to the bank, which could take a long time. In the meantime, the relevant amount remained blocked on the account of the depositor who had paid with the *Fede di Credito*. Remarkably, the Naples public banking system was, taken together, during most of the 18th century of an order of magnitude comparable to the one of the Bank of England, despite the fact that it did not rely on the further power of modern banknotes to enlarge the reach and scale of central banking. Nevertheless, banknote issuance brought a further break-through in the effectiveness of central banks to provide to the economy a universally accessible, efficient means of payment (as illustrated first by the Bank of England). Deposits had the advantage that they could not get lost, be destroyed or stolen. Also, they had the potential advantage that their transfer is documented and thereby auditable.

Whether banknotes and deposits are of a fundamentally similar or different nature has been a heated issue of debate during the 18th and even more during the 19th century, whereby banknotes tended to

be associated for a long time with higher risks in terms of tempting (central) banks to over-issue until they become illiquid and default. This view was inspired by examples such as the Stockholm Banco which had to be saved in 1664 and the Banque Royale of John Law, which failed in 1720. Reflecting this differentiation, for example Peel's Act of 1844 constrained the ability of the Bank of England to issue banknotes, but not to issue deposits. The literature comes back to the topic again and again, like Büsch (1801, 4-6) and Dunbar (1906). Dunbar (1906, 243) is surprised that the act establishing the Reichsbank in 1875 makes such a difference in terms of imposing liquid reserves on banknote-, but not on deposit issuance:

"These restrictions seem to illustrate the exaggerated importance which is still ascribed to the issue of notes on the continent of Europe. Notes are still regarded as the one important factor in the phenomena which result from the operations of banks, and the essential similarity in most respects of notes and deposits is overlooked"

That notes were deemed more vulnerable to cause runs, especially as long as multiple note-issuing banks were competing as it was the case in parts of the 19th century, may have been justified to some extent. The universal access to them (as also people physically remote to the issuing institution could hold banknotes) gave possibly more scope for an unstable demand. Still in 1924, the Dawes plan requested that the new Reichsbank statutes would foresee a precious metal reserve ratio for banknotes of one third, without constraining deposit issuance. Eventually, the concept of the monetary base, which sees banknotes and central bank deposits as fundamentally equivalent forms of money, conquered monetary economics as of the 1930s. Moreover, the switch to a paper standard after the end of the Bretton Woods system made the problem of over-issuance of central bank money less relevant, at least from the angle of convertibility. The table below provides an overview of which types of central bank liabilities (deposits or banknotes) were issued by some selected pre-1800 central banks, and of their relative relevance in the last decades of the 18th century (see Bindseil, 2019).

Table 2: Forms of central bank money in six early central bank balance sheets, averages for periods within 1770-1811 (source: Bindseil, 2019, which also contains the data sources).

	Bank of Amsterdam	Hamburger Bank	Bank of England	Riksbankens Ständers Bank	Caisse d'Escompte	Bank of the United States
Time period	1770-1800				1777-1792	1792-1811
Giro deposits issued / total BS	1.00	1.00	0.12	0.06	0.09	0.26
Banknotes issued / total BS	0.00	0.00	0.33	0.47	0.41	0.18
Banknotes / deposits	0.00	0.00	2.75	7.8	4.6	0.7

It is noteworthy that deposits have not only been the original form of central bank money (sometimes including remote-access techniques, like the *fede di credito* of Naples), but that for a long time, the feeling has occasionally been expressed that banknotes might not be the ultimate form of central bank money either, but only a temporary one, that will be replaced again one by deposits, being eventually superior. For example, in the words of Ulens (1908, 5):

*"No-one is questioning today the advantages of fiduciary money; the advantages of replacing metallic money with it are universally accepted. That fiduciary money takes the form of banknotes... is far from being the last word of progress. Much more perfect will be the mechanism of exchange based on current account deposits. ... But we are not yet there. ... The love of gold for its own sake has been replaced by the love of the banknote for its own sake."*⁵

⁵ "Il n'est plus personne aujourd'hui qui mette en doute les avantages de la circulation fiduciaire; il est universellement admis que la monnaie métallique peut être avantageusement remplacé... Cette circulation, représentée... par le billet de banque ... ,

The broad access to central bank deposits continued generally until the mid of the 20th century. The following table provides evidence of the share of bank, non-bank private, and public overnight deposits with German 20th century central banks. Bank deposits became clearly dominant only after WWII, while before, non-bank private deposits played a significant role. Non-bank private deposits were marginal as of the 1960s.

Table 3: Reichsbank / Bank Deutscher Länder/Bundesbank: share of different types of depositors

	Banks	Non-bank private	Public
1914	39%	16%	45%
1925	16%	19%	65%
1938	53%	40%	7%
1948	50%	7%	43%
1960	81%	1%	18%
1970	79%	1%	20%

(Source: Reichsbank, 1925, Bundesbank, 1976)

It would deserve a study on its own to review the decisions and justifications that led central banks to restrict more and more in the course of the 20th century the access of non-banks to central bank accounts (such as in the case of the German central banks). De Kock (1939, 10) notes that

“As regards their business relations with customers other than Governments and banks, the range varied from the Bank of England, which by the end of the nineteenth century had already come to give up most of its commercial banking business and to deal mainly with operators in the money market, to the Banque de France, which had a large number of branches and conducted a large business with regular clients, including many small tradesmen all over the country.”

Moreover, De Kock (1939, 327-332) identifies it as one amongst four big trends in central banking at that time to restrict direct dealings with the public. He quotes various central bank laws of the 1930s which restricted central banking business accordingly, although mostly he refers to lending operations of the central banks. Also, the five arguments he provides in favor of this trend all refer to lending operations of central banks, and not to the opening of deposit accounts. However, actually most of the arguments could also be applied to the central bank's liability side. In addition, for the liability side, growing awareness of the issues of structural and cyclical (i.e. crisis-related) bank disintermediation may have played a role as well. The traumatic experience of the repeated and wide-spread bank runs in the early 1930s was probably in the minds of central bankers for the subsequent decades. The rest of the 1930s and the 1940s were characterized by banks being mostly in excess liquidity vis-à-vis the central bank, but once conditions normalized in the 1950s, central banks may have concluded that, as a lesson from the early 1930s, bank runs should be made more difficult by eliminating non-bank private deposits.

From this review of practices over the last centuries, two key points can be retained for CBDC: *First*, deposits with unconstrained access for all types of depositors were the original form of central bank monetary liabilities, and neither banknotes, nor deposits restricted to commercial banks. Even some sort of remote use of deposits was practiced at a large scale starting in the 1580s in Naples in the form of the

est loin d'être le dernier mot du progrès. Bien plus parfait serait le mécanisme des échanges qui aurait pour base les dépôts en compte courants. ... Mais nous n'en sommes pas encore là.... L'amour de l'or en tant qu'or a été remplacé par l'amour du billet de banque en tant que billet de banque..."

Fede di Credito. Since access to deposits was not constrained during the first centuries of central banking, any household or firm could open an account provided it deposited a possible minimum deposit amount. The current restriction of central bank deposits to banks (besides public deposits) was only implemented around 70 years ago. In this sense, it could be argued that moving to CBDC would be returning to the roots of central banking. *Second*, for a long time, i.e. from the Riksbank's first unsustainable issuance of banknotes in 1661-1664, to at least the Dawes Plan of 1924, banknotes were considered the more dangerous form of central bank liabilities, compared with deposits. It is useful to remind these centuries-long controversial (and inconclusive) discussions about the relative dangers of different forms of central bank liabilities in the context of CBDC, which are also controversially discussed from the same angle. History in any case suggests caution and to avoid pre-empting the conclusion that CBDC would constitute a particularly dangerous central bank liability. At least, such a conclusion should not be reached before considering tools to control CBDC.

3. The structural bank disintermediation issue

CBDC has both found support, and caused strong concerns, with regards to its impact on the structure and scale of bank intermediation. Advocates of "sovereign money" see bank disintermediation as precisely the goal of CBDC. Already Huber (1999, 18), an advocate of "sovereign money", had correctly identified the financial account implications of central bank money replacing bank-issued sight deposits:

"The credit claims of a bank on the loan-taking clients remain; the cash liabilities of a bank to the account-maintaining clients disappear, and the cash claims of the account-maintaining clients on the bank disappear equally; in exchange for the latter a credit claim of the central bank on the bank appears. These credit claims would be part of the assets on the balance sheet of the central bank, corresponding to the sums of non-cash money being registered on the liability side (neither of which are the case today)."

Others have strongly rejected the idea of CBDC inflating the central bank balance sheet at the expense of deposit funding of banks. For example, Pollock (2018), in a testimony to the *Subcommittee on Monetary Policy and Trade of the Committee on Financial Services United States House of Representatives*, argues that CBDC would lead to various distortions precisely because of bank disintermediation: on one side the central bank would benefit from an unfair competitive advantage in deposit collection and amass undue power and market share (also likely misusing its regulatory powers to further strengthen its unfair advantages), on the other hand it would have competitive disadvantages in credit provision, which it would however ignore, leading to inefficiency, conflicts of interest and financial losses that eventually the taxpayer would have to bear.

CPMI-MC (2018, 2) also express somewhat similar concerns that structurally, CBDC could have negative effects on credit allocation and thereby economic efficiency:

"Introducing a CBDC could result in a wider presence of central banks in financial systems. This, in turn, could mean a greater role for central banks in allocating economic resources, which could entail overall economic losses should such entities be less efficient than the private sector in allocating resources. It could move central banks into uncharted territory and could also lead to greater political interference."

Carstens (2019) reiterates such worries (see also Mancini-Griffoli et al, 2018, 21-24). Finally, CPMI-MC (2018, 2) emphasizes the cross-border issues that CBDC may create. Indeed, also for banknotes, foreign demand has been a major factor in recent decades (e.g. Jobst and Stix, 2017). CBDC, if offered in the same perfectly elastic way as banknotes, could facilitate further the cross-border access to central bank money:

“For currencies that are widely used in cross-border transactions, all the considerations outlined above would apply with added force, especially during times of generalized flight to safety. The introduction of a CBDC in one jurisdiction could adversely affect others. Central banks that have introduced or are seeking to introduce a CBDC should consider cross-border issues where relevant.”

Below the creation of CBDC is captured in a financial account system, which very broadly replicates the euro area financial accounts as of Q2 2018 (as provided in the ECB Statistics Warehouse or the ECB Economic Bulletin). The accounts are simplified in particular with regards to netting and that the non-bank financial sectors (OFIs and ICPFs, i.e. “other financial institutions” and “insurance companies and pension funds”) have been left away, or been broadly integrated into the household sector. Also, the ECB’s asset purchase program is not reflected.

If households substitute banknotes with CBDC, then central bank and commercial bank balance sheets do not really change. However, if households substitute commercial bank deposits with CBDC, then this would imply a funding loss for commercial banks and could lead to “disintermediation” of the banking sector. In particular sight deposits with low remuneration could be expected to shift at least to some extent into riskless CBDC, leading to a loss of commercial banks’ funding of equal size. Banks would have to try to offer better conditions on their deposits in order to protect their deposit base as much as possible – but this would imply higher funding costs for banks and a loss of commercial bank “seignorage”. Below, the creation of CBDC has thus been split into two parts: **CBDC1** which substitute banknotes and **CBDC2** which substitute deposits with banks. It seems most likely that indeed CBDC would do both of those, but it is unclear with what weights. The effect of CBDC1 on the rest of the financial accounts is neutral, but the effects of CBDC2 are not: CBDC2 lengthens the central bank balance sheet as central bank credit will have to fill the funding gaps of the banks. The central bank may want to avoid this effect by purchasing government and corporate bonds, whereby the source of the bonds could be either households or banks, being captured in the financial accounts by **S1** and **S2**, respectively. In the former case, it has been assumed here that the households will not keep the money obtained in the form of bank deposits, but would purchase bank bonds that the banks would in addition issue (however, from a financial account perspective, it makes no difference if the purchases of bonds by the central bank from households imply additional deposits with banks or additional capital market investments of households into bank bonds). Finally, the financial accounts also show the case in which the banks would truly shrink their economic activities by reducing their loans to corporate (**DL** for “deleveraging”), whereby it is assumed that the corporates issue additional corporate bonds to compensate this loss of funding, and the central bank purchases these bonds.

Figure 1: Financial accounts representation of CBDC, compensating securities purchases by the central bank, and possible bank deleveraging (numbers in trillion of euro broadly illustrating euro area accounts)

Households, pension and investment funds, insurance companies				
Real Assets	20		Household Equity	40
Sight deposits	5	-CBDC2		
Savings + time deposits	4		Bank loans	5
CBDC		+CBDC1 +CBDC2		
Banknotes	1	-CBDC1		
Bank bonds	4	+S1		
Corporate/Government bonds	7	-S1		
Equity	8			
Corporates				
Real assets	13		Bonds issued	3 +DL
Sight deposits	2		Loans	8 -DL
Savings deposits	1		Shares / equity	5

Government			
Real assets	11	Bonds issued	9
		Loans	2
Commercial Banks			
Loans to corporates	8 -DL	Sight deposits	7 -CBDC2
Loans to government	2	Savings + time deposits	5
Loans to HH	5	Bonds issued	4 +S1
Corp/state bonds	5 -S2	Equity	3
Central bank deposits	0	Central bank credit	1 +CBDC2 -S1-S2-DL
Central Bank			
Credit to banks	1 +CBDC2 -S1-S2 -DL	Banknotes issued	1 -CBDC1
Corp/Government bonds	0 +S1+S2 +DL	Deposits of banks	0
		CBDC	+CBDC1 +CBDC2

While CBDC1 appears uncontroversial as it merely substitutes one form of central bank money into another without changing the rest of the financial system, CBDC2 increases the dependence of banks on central bank credit and decreases sight deposits with the banking system. Both S1 and S2 have positive effects in the sense that they reduce again the dependence of banks on central bank credit. CBDC2 will obviously have effects on funding costs of the banking system, as typically central bank credit and bond issuance are more expensive than the remuneration rate of sight deposits (except in unusual circumstances, as the ones prevailing e.g. in the euro area since 2014, in which obtaining credit from the central bank was partially possible for banks at negative rates, while sight deposits of households with banks remained non-negative). Moreover, a larger recourse to central bank credit could lead to collateral scarcity issues and the question whether the central bank collateral framework becomes so crucial from a credit allocation perspective that one would observe an effective centralisation of the credit provision process. Both effects will be analysed further in the next two subsections.

Effects on bank funding costs of CBDC2

Following Juks (2018, section 4.2-4.3), one needs to understand what impact CBDC will have on average funding costs of banks, and therefore on bank lending rates (see also e.g. Engert and Fung, 2017). In addition, it should be understood how this may impact monetary policy interest rate setting of the central bank and the seignorage income of the central bank. Bank funding costs will obviously increase because a cheap funding source (sight deposits) decreases, and more expensive funding sources (central bank credit or bank bond issuance) have to take over. The central bank would have to compensate the implied tightening of financial conditions caused by a decrease of cheap sight deposit financing of banks by *lowering* the monetary policy rate. The extent of the required lowering of short-term interest rates would depend on the size of CBDC2, on the relative share of bank funding in the economy, and on the spread between the other bank funding rates with the monetary policy operations rate. Moreover, substitution effects from bank-based to capital market-based financing of the economy would impact on the overall needed adjustment of central bank rates. The fact that bank funding is only one part of overall funding of the economy implies that the central bank will not reduce the short-term interest rates in a way that bank funding costs are stabilized, but only partially so. Therefore, in the new equilibrium, banks will have lost competitiveness and will lose some market share relative to other forms of funding (though capital markets and non-bank intermediaries).

Table 4a and 4b provide the average levels of the relevant shares and interest rates for the period 2003-2008, and 2009-2018, respectively (Data sources: bond yields Merrill Lynch; all other data: ECB).

Table 4a: Euro area bank funding costs across different instruments, 2003 - 2008

	Share in bank funding	Average interest rate
Deposits (in M3)	44%	1.83%
Other deposits	13%	3.25%
Bonds issued	30%	4.10%
Equity issued	10%	8.47%
Central bank credit (MRO rate)	3%	2.79%

Table 4b: Euro area bank funding costs across different instruments, 2009 - 2018

	Share in bank funding	Average interest rate
Deposits (in M3)	47%	0.78%
Other deposits	14%	2.39%
Bonds issued	23%	2.15%
Equity issued	12%	10.54%
Central bank credit (MRO rate)	4%	0.50%

The largest share in bank funding came from deposits with residual maturity of less than two years and redeemable at three- or less month notice, i.e. the types of deposits contained in the monetary aggregate M3. This is also the cheapest funding source in the first period, while in the second period, central bank funding becomes even cheaper. Actually, overnight deposits contribute 50-65% of these deposits, and have a significantly lower interest rate. For example, in December 2005, new overnight deposits were remunerated on average at 0.71% while up to one-year term deposits at 2.15%.

What happens to overall **central bank income** because of CBDC2? Two effects partially compensate each other: the increase of the monetary base, against the needed lowering of interest rates. The net effect will in any case be an increase of central bank income and an increase of overall bank funding costs⁶. For example, assume that the 2003-2008 data applies, and that 10 percentage points of M3-deposits of banks are substitute with CBDC2, and that CBDC is not remunerated. If everything else remains unchanged, then the funding costs of banks increase by $0.1 \times (2.79\% - 1.83\%)$, i.e. around 10 basis points. If the central bank wants to keep financial conditions unchanged, it needs now to lower the general interest rate level. If bank funding is 50% of total funding of the economy, the rest being capital market based, then the central bank will have to lower the interest rate level by 5 basis points if it wants to achieve that the average funding costs of the real economy stay unchanged (and if one ignores secondary effects). The central bank's income will have evolved as follows: $13\% \times 2.74\% - 3\% \times 2.79\% = 0.13\%$ of the balance sheet length of banks. Depositors will have given up $10\% \times 1.83\%$ of income, i.e. 0.18% of the balance sheet length of banks (which they do voluntarily because they were assumed to choose this shift out of preference for CBDC). Average funding costs of banks will have increased by 5 basis points, and costs of capital market financing will have decreased by the same amount, implying some loss of competitiveness of banking.

Increase of banks' reliance on central bank credit, collateral constraints, and credit centralisation?

To what extent could CBDC undermine the decentralised, market-based financing of the real economy by increasing massively the central bank balance sheet, and thereby making it, either via increased central bank securities holdings, or via an increased funding of banks through central bank credit, an important (but potentially inefficient) element of the credit allocation process?

⁶ A case of declining central bank income could be constructed if CBDC would replace banknotes and would have a higher remuneration rate than banknotes.

State liabilities can be stores of value for households, in particular if they are matched, in the state balance sheet, by real assets that the state owns. However, probably the state would not want to become a financial intermediary for household savings, which would happen if the state re-invested proceeds from issuing debt to households in the form of financial assets, or in the form of real assets not linked to state tasks, just for the sake or re-investment. This logic may also be applied to central banks in a somewhat different way as central banking starts from the liability side: to the extent they issue means of payment, they need to re-invest the proceeds from doing so. However, the central bank probably does not want central bank money to become a large-scale store of value, i.e. investment vehicle, as this would mean that the central bank would become a financial intermediary. Turning to the asset side of the central bank balance sheet, one may note different views of central banks on what is the best match with its monetary liabilities: The Fed and the Bank of England systematically invested the proceeds from the issuance of banknotes into government paper. The Deutsche Bundesbank in contrast traditionally considered exposures of the central bank to the government as problematic and therefore preferred assets in the form of loans to banks collateralised with high quality securities or bills of exchange.

In view of the outstanding levels of government debt in developed economies (end 2018 levels for e.g. the euro area and UK around 85%; US around 105%; Japan around 235%), and the much lower level of banknotes in circulation so far (around 10% of GDP for advanced economies, and 8% for emerging economies, see e.g. Riksbank, 2018, 6) it would appear that there would be some scope for CBDC2 to be matched on the central bank asset side with higher holdings of government bonds, such that neither (i) the reliance of banks on central bank credit would need to increase, nor (ii) would the central bank have to hold a credit risk intense portfolio of securities. In any case, currently at least the central banks of the UK, Japan and the Euro area hold large QE related portfolios that created large amounts of excess reserves of banks, that would provide scope for CBDC2 of at least the size of banknotes in circulation before reserve scarcity would emerge (without any further purchases of government bonds). Moreover, once the potential for matching CBDC with government exposures would have been exhausted, the central bank can still try to minimise the impact of the lengthening of the central bank balance sheet on the credit allocation process by aiming at diversified exposures to the private sector (e.g. outright holdings of various securities types and issuers proportional to market capitalisation; credit operations with banks against a broad collateral set).

In so far, it could be argued that there is some scope for CBDC2 before the central banks would have to accept really credit-intense exposures to the private sector, and thereby play a potentially larger role in the credit allocation of the economy, which may eventually be negative for the overall efficiency of the economy. Only if CBDC2 takes even much larger dimensions, such as desired by the promoters of sovereign money, then an issue relating to the centralisation of credit would emerge. For example, in the euro area financial accounts, as shown in a very simplified way in the financial accounts system above, the full shift of all sight deposits with banks to CBDC2 (as wished by sovereign money supporters) would increase the minimum balance sheet of the central bank from EUR 1 trillion to 8 trillion. Currently, the Eurosystem holds outright policy portfolios of more than 2.5 trillion plus other securities and foreign reserves of around 1.5 trillion, bringing its actual balance sheet to EUR 4 trillion. Therefore, without additional securities purchases, it would have to provide credit of around EUR 4 trillion to banks (everything else unchanged), i.e. 20% of the banks' balance sheets. This would probably force the ECB to revisit its collateral framework, such as to accept in addition some asset classes it formerly did not accept, like portfolios of mortgage loans. If haircuts on loans would be in the order of magnitude of 30%, then banks should normally be able to provide sufficient collateral for the extended amount of central bank credit needed (even before they would try to find other financing sources, such as an increased issuance of equity or of bank bonds to households, and before the central bank would increase its outright portfolios of government securities). However, it needs to be acknowledged that the impact of

the central bank collateral on asset prices (and yields) would tend to intensify (see e.g. Bindseil, Corsi, Sahel and Visser, 2016, and Nyborg, 2016, for discussions on how the collateral framework of the central bank may impact on relative asset prices). Unless one is a supporter of sovereign money, one will therefore be interested in finding solutions to effectively control the volume of CBDC, to make sure that it will not lead to any centralisation of the credit allocation process.

Finally, as noted by Juks (2018, 84), a large shrinkage of the deposit base of banks and a replacement with other liabilities will also have implications on the ability of banks to fulfil regulatory liquidity requirements. Indeed, household deposits are treated as a rather stable liability class in most regulations, such that their decline will tend to make it more difficult for banks to comply and require possibly further costly adjustments which could make maturity transformation more expensive.

4. Bank runs into CBDC

Mersch (2018), amongst others, has emphasized the destabilizing effects of CBDC in a financial crisis, namely its facilitation of a run on the banking system:

During a systemic banking crisis, holding risk-free central bank issued DBM [CBDC] could become vastly more attractive than bank deposits. There could be a sector-wide run on bank deposits, magnifying the effects of the crisis. Even in the absence of a crisis, readily convertible DBM could completely crowd out bank deposits – putting the existence of the two-tier banking system at risk. In this situation, the efficient flow of credit to the economy would likely be impaired.

CPMI-MC (2018, 2) also supports the view that CBDC could make worse bank run dynamics in a crisis:

“The introduction of a CBDC would raise fundamental issues that go far beyond payment systems and monetary policy transmission and implementation. A general purpose CBDC could give rise to higher instability of commercial bank deposit funding. Even if designed primarily with payment purposes in mind, in periods of stress a flight towards the central bank may occur on a fast and large scale, challenging commercial banks and the central bank to manage such situations.”

Also Mancini-Griffoli et al. (2018, 24-25) discuss this aspect of CBDC, but conclude that overall these effects are likely to be muted.

A run on commercial banks can take three forms in principle⁷, if one makes the distinction from the perspective of where the deposits flow to, namely: “R1”, into deposits with other banks, i.e. within the banking system; “R2”, into banknotes, i.e. the classical physical bank run where queues could arise in front of bank branches and ATMs; “R3”, into non-bank deposits with the central bank, which in the past decades was limited to deposits of official sector institutions, but in the future could be facilitated by CBDC. In the financial accounts below, these three flows are shown as originating from the household/investment sector. In contrast to figure 1, two separate banks constituting the banking system are now distinguished, such as to allow representing R1.

⁷ Juke (2018, section 5) also distinguishes three forms of runs, although not identical ones. Still the conclusions are rather similar.

Figure 2: Financial accounts representation of bank run, distinguishing between three targets of flows

Households, pension and investment funds, insurance companies			
Real Assets	20	Household Equity	40
Sight deposits bank 1	2.5 $-R1 -R2/2 -R3/2$	Bank loans	5
Sight deposits bank 2	2.5 $+R1 -R2/2 -R3/2$		
Savings + time deposits	4		
Deposits with central bank			
Banknotes	1 $+R2$		
Corporate/gvt bonds	7		
Bank bonds and Equity	12		
Corporates			
Real assets	13	Bonds issued	3
Sight deposits	2	Loans	8
Savings deposits	1	Shares / equity	5
Government			
Real assets	11	Bonds issued	9
		Loans	2
Commercial bank 1			
Loans to Corporates/Gvt/HH	7.5	Sight deposits	3.5 $-R1 -R2/2 -R3/2$
Corp/gvt bonds	2.5	Savings + time deposits	2.5
Central bank deposits	0	Bonds and equity issued	3.5
		Central bank credit	0.5 $+R1 +R2/2 +R3/2$
Commercial bank 2			
Loans to Corporates/Gvt/HH	7.5	Sight deposits	3.5 $+R1 -R2/2 -R3/2$
Corp/gvt bonds	2.5	Savings + time deposits	2.5
Central bank deposits	$\max(0, -(0.5 -R1 +R2/2 +R3/2))$	Bonds and equity issued	3.5
		Central bank credit	$\max(0, 0.5 -R1 +R2/2 +R3/2)$
Central Bank			
Credit to banks	$0.5 +R1 +R2/2 +R3/2 +\max(0, 0.5 -R1 +R2/2 +R3/2)$	Banknotes issued	1 $+R2$
Corp/state bonds	0	Deposits of banks	$\max(0, -(0.5 -R1 +R2/2 +R3/2))$
		Non-bank deposits	$R3$

Note that $R2$ and $R3$ are observable in aggregate accounts while $R1$ is not. Indeed, $R1$ does not become visible in the aggregate accounts until the bank benefitting from deposit inflows has paid back all of its central bank credit. Moreover, $R1$ would have to be extracted from the excess reserves of banks which are also influenced by $R2$ and $R3$ (and, in reality, there are obviously not only two banks). The table below captures the importance of the three types of runs, again with the above-mentioned caveat for $R1$. Moreover, the Eurosystem somewhat invited the creation of excess reserves in 2011 through particularly attractive credit operations, so that the increase of excess reserves overestimates the inter-banking system run.

Table 5: Indicators of run on bank deposits, 2008 and 2011, Eurosystem

	Δ in % of stock at beginning of period			Δ in % of Eurosystem balance sheet at beginning of the period		
Comparison between December averages of:	Banknotes ("R2")	Excess reserves of banks	Excess reserves of non-bank depositors ("R3")	Banknotes ("R2")	Excess reserves of banks	Excess reserves of non-bank depositors ("R3")
2008 vs 2007	+13%	+3675%	+ 321%	+7%	+32%	+23%
2012 vs. 2010	+8%	+580%	+151%	+4%	+38%	+10%

The table suggests that the contribution of a run from bank deposits into banknotes was remarkably small compared to the two other factors. The run from weak into strong banks was clearly the strongest amongst the three, followed by the run into non-bank deposits.

It may be recalled that the spread between the rate on the ECB's main refinancing operations (MRO – conducted as a so-called “fixed rate full allotment”) and the rate of remuneration of excess reserves is the tool to set incentives against a run from deposits with one bank into the deposits of another bank. However, if anything, the Eurosystem *narrowed* this spread during the crisis episodes, relative to the pre-crisis level of 200 basis points, suggesting that trying to prevent a run through price incentives was not considered the right solution (see e.g. Bindseil and Jablecki, 2011).

To understand better the drivers of R3 over the last decade, the figure below reports the evolution of three liability positions of the Eurosystem that capture non-bank deposits open to different public sector entities, namely (according to Annex IV of the ECB's accounting guideline, see ECB, 2016):

- L.5.1 “**General Government.** Current accounts, fixed-term deposits, deposits repayable on demand”
- L.5.2 “**Other liabilities.** Current accounts of staff, companies and clients including financial institutions listed as exempt from the obligation to hold minimum reserves (see liability item 2.1 ‘Current accounts’); fixed-term deposits, deposits repayable on demand”
- L.6 “**Liabilities to non-euro area residents denominated in euro.** Current accounts, fixed-term deposits, deposits repayable on demand including accounts held for payment purposes and accounts held for reserve management purposes: of other banks, central banks, international/supranational institutions including the European Commission; current accounts of other depositors. Repo transactions in connection with simultaneous reverse repo transactions for the management of securities denominated in euro. Balances of TARGET2 accounts of central banks of Member States whose currency is not the euro.”

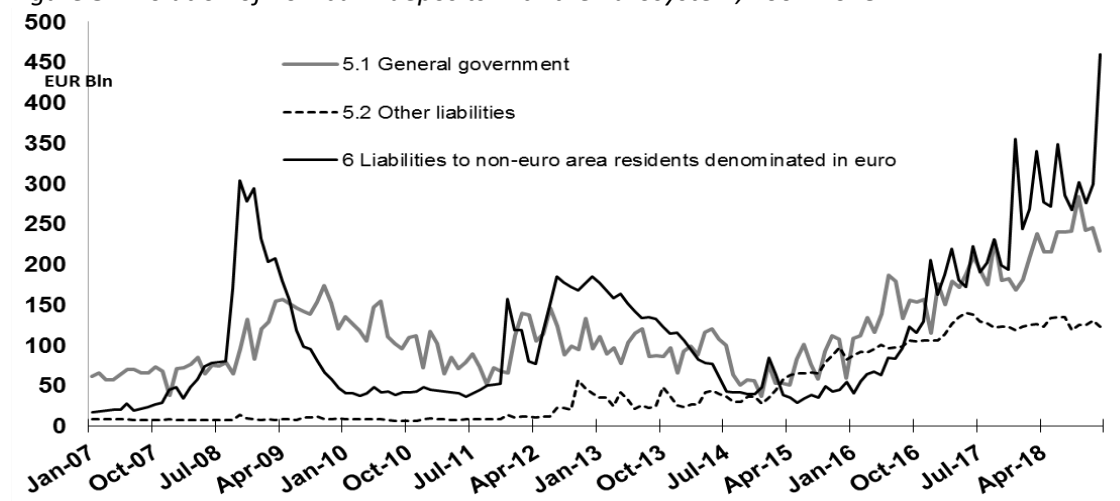
The figure suggests that the pricing of non-bank deposits by the Eurosystem was not such as to prevent any increase of non-bank liabilities in each of the three balance sheet expansions over the last years:. During the banking crisis in 2008, in particular L6 increased steeply and rapidly, peaking in December 2008, while L5 increased more gradually. During the sovereign debt crisis, again L6 reached high levels, this time peaking in July 2012. The highest levels were reached for all three types of deposits during the asset purchase program APP, with the peaks being reached with the maximum level of APP stocks in December 2018.

Actually, three special factors have to be distinguished during these phases. First, in particular during 2008, but also again during 2011-2012, strong perceptions of credit riskiness with regards to at least parts of the banking system triggered withdrawals of deposits. From the perspective of the banks with deposit outflows, it makes no particular difference if the outflows of a certain amount benefit other banks, go to some non-bank deposit account with the central bank, or take the form of banknotes (as explained above, see also Juks, 2018, section 5). Second, exceptional levels of central bank rates had implications on the relative attractiveness of different investments. For example, if the remuneration rate of some non-bank deposits is set to be zero by the central bank, this may normally, i.e. in the old world of positive interest rates, have been considered unattractive, and as ensuring that the amounts deposited will remain low. But once monetary policy interest rates move, contrary to previous assumptions, to zero or even to below zero, then the previously unattractive (tier two) non-bank deposit remuneration rates become attractive, until the central bank changes the rate setting formula to react to the new reality. Indeed, the Eurosystem adjusted its formulas, although not in a way to fully prevent an increase. Third, exceptional amounts of excess reserves pushed some short-term market rates to below the level of the deposit facility accessible to banks. For example, GC repo overnight rates traded in 2017-

2018 around 15 basis points below the rate of the deposit facility, which would have been unthinkable in normal liquidity conditions.

As mentioned, the Eurosystem would not have needed to tolerate these episodes of increase of non-bank deposits, i.e. by pricing deposits more aggressively. For example if the Eurosystem would have remunerated them at -5%, it would have prevented a large increases of these deposits, as the official sector investors would then have preferred to invest in AAA rated government bonds. That the Eurosystem did not do so reveals the judgement of the Eurosystem that the observed increase of non-bank deposits was acceptable both from the perspective of financial stability and monetary policy.

Figure 3: Evolution of non-bank deposits with the Eurosystem, 2007-2018



5. Controlling CBDC volumes –approach by Noone and Kumhof (2018)

CBDC should be launched only if the central bank can be confident that the issues discussed in the previous two sections – undesired structural disintermediation of the banking system, and avoidance in systemic crises of a facilitation of aggregate bank runs – have been solved. Supporters of CBDC have acknowledged these issues, and in particular Kumhoff and Noone (2018) have devoted substantial efforts to design solutions to them. Their approach relies on four key principles (from their abstract):

“We find that if the introduction of CBDC follows a set of core principles, bank funding is not necessarily reduced, credit and liquidity provision to the private sector need not contract, and the risk of a system-wide run from bank deposits to CBDC is addressed. The core principles are:

- (i) CBDC pays an adjustable interest rate.*
- (ii) CBDC and reserves are distinct, and not convertible into each other.*
- (iii) No guaranteed, on-demand convertibility of bank deposits into CBDC at commercial banks (and therefore by implication at the central bank).*
- (iv) The central bank issues CBDC only against eligible securities (principally government securities).*

The final two principles imply that households and firms can freely trade bank deposits against CBDC in a private market, and that the private market can freely obtain additional CBDC from the central bank, at the posted CBDC interest rate and against eligible securities.”

While Kumhof and Noone (2018) correctly identify the issues that need to be addressed, the solutions they propose through their four principles may partially contradict the initial intuition of central bank market operations practitioners. Below, each of the principles of Kumhof and Noone are discussed in somewhat more detail. Subsequently, in section 6, a simple alternative is proposed. Bjerg (2018) also discussed in detail the four principles of Kumhof and Noone, although from a different perspective and coming to different conclusions. Juks (2018, section 5.2.3) also touches briefly on some of the principles, although without providing an assessment.

Principle 1: “CBDC pays an adjustable interest rate”

Indeed, CBDC should be designed such that a non-zero interest rate can be applied to it. Kumhof and Noone’s justify this principle as follows (p. 8):

“Equilibrium in the market for CBDC requires a price to equilibrate demand and supply. Assume that CBDC pays a fixed nominal interest rate of zero, like cash, and that the central bank oversupplies CBDC to the market, perhaps because its estimate of the demand for real CBDC balances is imprecise. We now ask: which price can clear the market by eliminating the oversupply? The first possibility is that CBDC depreciates relative to other forms of money, in other words parity breaks down. This is highly undesirable from the central bank’s point of view, but it may be possible to avoid this through the design of the CBDC issuance mechanism, which we will discuss further below. The second possibility is that the exchange rate remains fixed at parity but the general price level clears the market, by reducing the real value of nominal CBDC balances and bringing them in line with the real demand for CBDC. This would directly challenge the anti-inflationary mandate of the central bank, and is therefore also highly undesirable.”

The question may arise why the issues described in this excerpt would not apply to banknotes in circulation, which indeed “pay a fixed nominal interest rate of zero”. The answer to a theoretical “oversupply” seems to be in practice a “reflux” of CBDC into the central bank, via banks, in the same way as it would happen for banknotes. For example, after the Christmas shopping peak of banknotes, banknotes return to the central bank and generate thereby additional reserves of the banks with the central bank, i.e. the level of a liquidity absorbing autonomous liquidity factor declines (see e.g. Cabrero et al, 2002). The same would happen to CBDC (for a given remuneration level below the risk-free interest rate), which the central bank would, in its liquidity management, also simply regard as an autonomous factor. Because of the assumption, appearing obvious to central bank market operations practitioners, of unconstrained convertibility of different forms of central bank money (reserves, banknotes, CBDC), i.e. not setting the quantity on any form of central bank money, nor on the total sum of it, the “parity breaks down” scenario seems per se excluded.

The second perceived danger, namely that inflation is needed to address the assumed over-supply of CBDC, also would not come to the mind of central bank market operations practitioners, for the same reasons as an over-supply in banknotes is not perceived as possible cause of inflation. Central banks monitor, in a forward-looking manner, all factors impacting on inflation in the medium term. They then adjust their target for some overnight interest rate, which is the anchor for the short end of the risk-free yield curve, such that the necessary monetary impulses are generated, to achieve price stability in the medium term. The control of overnight interest rates typically works through setting central bank standing facilities rates at the adequate level, and controlling reserve conditions such as to be compatible with some level of interest rates within the corridor set by standing facilities (e.g. Bindseil, 2014, 36-41; 51-61). From this perspective, it does not seem that an over-supply of CBDC or of banknotes by the central bank could challenge the anti-inflationary mandate of the central bank. Excess supply returns into the central bank in the form of bank reserves through convertibility, and the central bank will correspondingly reduce its supply of reserves through reducing open market operations volume, such as to keep reserve conditions stable.

In sum: it seems that the remuneration of CBDC is per se neither necessary to clear a market, nor to control inflation, in analogy with the case of banknotes, which also cause none of these issues⁸. However, still, the ability to remunerate CBDC, in contrast to banknotes, is a privilege that has a number of advantages. It allows shifting the interest rate on CBDC in principle in parallel to monetary policy rates, such as to avoid that the relative attractiveness of CBDC relative to market- and central bank policy rates depends on the absolute level of interest rates, as it is the case for banknotes. Indeed, the fact that the remuneration of banknotes stands at zero regardless of whether short-term risk-free rates are at 10% or at -0.5% (as currently in the euro area) may be perceived as an anomaly, which becomes increasingly problematic when the zero lower bound is being approached or passed. Moreover, a negative remuneration of CBDC also allows addressing the possible danger of a run into CBDC in case of a systemic banking crisis (as also noted by Kumhof and Noone). As shown in section 4, in the 2008 banking-, and 2011/12 euro area debt crises, a run into banknotes played only a rather minor role, relative to the run from perceived weak to perceived strong banks – despite the fact that the remuneration of banknotes remained at zero, and that the level of short term risk free rates quickly approached this level after the Lehman default, reducing the opportunity costs of holding banknotes. Nevertheless, since a run into CBDC would be easier, it would be comforting to have as extra tool the ability to impose negative rates on CBDC.

Moreover, Kumhof and Noone (p. 11) argue that interest on CBDC could be used as a further monetary policy instrument:

“...why would the authorities give up control over a second policy instrument when there is no necessity to do so, and knowing that ... there is at least a chance that this second instrument could make a substantial contribution to stabilizing the economy?”

The use of interest rates on CBDC as an independent macroeconomic monetary policy tools is formalized in Barrdear and Kumhof (2016) in a state-of-the-art monetary model.

From the practical perspective of central bank operations, the remuneration rate of CBDC may be perceived less as an independent monetary policy instrument, but more as an instrument similar to the other spreads between ECB policy rates and the remuneration rates of specific deposit accounts. These rates (or spreads relative to the key policy rate) may pursue specific objectives in terms of incentivizing behaviors of those for which these rates are relevant, including e.g. incentives to rely on the central bank vs. relying on market-based alternatives, with repercussions on the central bank balance sheet and on market functioning. They are not perceived as independent contributors to the monetary policy stance. The (overnight) interest rate on central bank reserves anchors the short end of the risk-free yield curve, and has established itself as the one and only operational target of monetary policy (Bindseil, 2014, 36-43). The various central bank operations rates – like in the case of the ECB, the rate of the main refinancing operations, the rate of the marginal lending facility, the rate of the deposit facility, and the zero rate on the remuneration of banknotes – are all not perceived as independent monetary policy rates. What matters for monetary policy at the end is the level of short-term market rates, and in particular the overnight interest rate on bank reserves with the central bank, as anchor of all other market interest rates. This principle should not change with the introduction of CBDC. The remuneration rate on CBDC would be chosen such that it would have, in normal times, a sufficient negative spread towards the short-term risk-free market rates, *so that CBDC would not become a large-scale store of value*. The remuneration rate on CBDC would be a “policy” rate only in the sense of this “policy”

⁸ An exception is the zero lower bound case.

objective, but not in the sense of a specific contribution to the stance of monetary policy. This view may reflect skepticism on the ability of central banks to manage a complex toolbox of operational variables to achieve monetary policy objectives. For example, starting in the 1920s, but culminating in the 1960s and 1970s, changes to reserve requirements, the conduct of open market operations, and the setting of interest rates were often presented as three independent tools that could be used independently to achieve monetary policy objectives even better. In subsequent decades, central banks gave up this ambitious attitude and seemed to accept that a single variable – the short end of the risk free yield curve – should be a sufficient measure of the monetary policy stance in normal times. Only in times of financial crises, or when monetary policy hits the effective lower bound, the financial conditions in a broader sense become the operational target.

Principle 2: “Reserves and CBDC are distinct and not convertible into each other”

As argued above, from the practical perspective of central bank market operations, it would seem to go against key assumptions that overnight liabilities of the central bank would be inconvertible from one into another form – even under special circumstances. Ever since banknotes and deposits with the central bank have co-existed, such convertibility was assumed. In a metal standard, this convertibility follows from the convertibility of any form of overnight central bank liabilities into metal, and therefore also into each other. Also, in a paper standard, sound central banking assumes convertibility of banknotes into deposits with the central bank, or vice versa. A central bank liability which is not fully convertible are central bank bills (or “debt certificates”). But in their case, the non-convertibility simply follows from their longer than overnight maturity, and they do not fall under the definition of central bank money. Kumhof and Noone (p.8-9) justify this principle with two objectives:

- *“First, it helps to safeguard financial stability when depositors seek to switch into CBDC in large numbers.”*
- *“Second, this principle enables reserves and CBDC to have a separate core purpose, in particular CBDC does not have to function as the interbank settlement asset or be bound by the same rules as RTGS. This allows the central bank to operate a second policy instrument, specifically the quantity of or the interest rate on CBDC.”*

Both arguments have been discussed already above in the context of principle 1. That different forms of central bank money have different “core purposes” has not led so far to the conclusion that one should under some circumstances suspend convertibility between them. In particular, both banknotes and deposits with the central bank obviously have somewhat different purposes, but they have always been assumed to be convertible into each other in the history of (central) banking. These issues have been discussed actually for a long time, and many will still agree with Dunbar’s (1906, 62-63) century old interpretation:

“...the belief has been common that banks are under a special and dangerous temptation to over-issue notes, thus causing their depreciation with loss to the public. The question whether really convertible notes can circulate in excess has been the subject of much wearisome and futile discussion... It has already been shown, however, that the question whether notes shall be issued or not, is one which in modern banking is not settled affirmatively by the bank, but is settled by the creditor, who determines for himself and with an eye to his own convenience, whether to hold his right, as against the bank, in the form of a note or a deposit.”

Principle 3: “No guaranteed on-demand convertibility of bank deposits into CBDC”

Kumhof and Noone consider that convertibility of deposits with banks into CBDC is not strictly needed:

It “is both dangerous and unnecessary. Why is it dangerous? The key consideration is the credibility of the obligation. The banking sector may be able to meet the obligation when the net flows into CBDC and out of

deposits are small and slow-moving. However, credibility also relies on being able to meet the obligation in times of stress. ... Banks would need to sell or repo eligible assets to the central bank to gain CBDC, with the central bank possibly having to expand the list of eligible collateral, or even to dispense with collateral requirements altogether in large-scale unsecured lending. The credibility of the obligation therefore turns on the central bank's commitment to be the lender of last resort, potentially taking an unprecedented risk onto its balance sheet given the potential size of the liquidity requirements. That is, the guarantee of banks to always stand ready to convert deposits to CBDC must ultimately be supported by a guarantee from the central bank."

However, it would need to be explained further why one core feature of overnight deposits with banks – i.e. convertibility on demand at any time into central bank money – would apply to central bank money in the form of banknotes, but not in the form of CBDC. Moreover, what if banknotes would eventually cease to exist, as it may be forecast at least for some countries like Sweden? This would seem to imply that banks would no longer promise unconditionally the convertibility of sight deposits into central bank money.

Principle 4: "The central bank issues CBDC only against eligible securities"

Kumhof and Noone (p. 17) explain that:

"The fourth core principle is that the central bank only exchanges CBDC for eligible securities of its choosing, such as government securities. It does not exchange it for reserves, ... and it also does not exchange it for bank deposits... This core principle allows the central bank to manage the risk to its own balance sheet from issuing CBDC, just as it does for reserves and cash. More importantly, these issuance arrangements can mostly eliminate the risk of an aggregate run out of the banking sector, either runs that become possible via a subset of banks when CBDC and reserves are exchangeable, or the generalized runs on the banking system that become possible via the totality of banks when CBDC and bank deposits are exchangeable on demand."

Indeed: when central bank money is created through credit operations with banks, then banks should submit collateral, and this should be independent of the form of central bank money that would eventually be created. The following points may be relevant in this context:

- Normally the only form of central bank money which is created through credit operations of the central bank with its counterparties is in the form of reserves. The banks then later on decide to convert reserves into other forms of central bank money, depending on the demand of their customer. The introduction of CBDC should not change this principle.
- It would need to be clarified how to operationalize "exchanging" eligible securities against CBDC. If the exchange would effectively be an outright purchase by the central bank, then this would mean the re-introduction of a kind of discount facility, i.e. where banks can bring eligible securities at their own initiative and sell them to the central bank which sets a discount rate to determine the price of the securities. In the past, when such discount operations still existed, they were however limited to short term paper, normally up to three months.
- With regards to how this arrangement would eliminate the risk for a run, two related factors seem relevant. First, one may argue that the central bank, by allowing banks to obtain more CBDC against eligible securities, essentially acts as an elastic ("horizontalist") provider of central bank money, and that this per se tends to make a run on banks less likely. Second, in case one has in mind outright purchases by the central bank of government debt, the recourse of banks to central bank credit is kept constant, meaning that on aggregate the banking system does not need to rely on ever growing central bank credit until being eventually collateral constrained.
- Relating to principle 2, it could seem counterintuitive that the central bank would convert eligible securities into CBDC, but not reserves into CBDC, i.e. eligible securities issued by someone else would

be treated better than the central bank's own overnight liabilities, which are supposed to be the least risky and most liquid amongst all financial assets in the economy.

Overall, it could be perceived that the principles of Kumhof and Noone, while aiming at controlling the effects of CBDC in a way that CBDC does not undermine too much the existing financial order, introduce changes to this order which are far reaching. In particular, core principles of banking and central banking relating to convertibility would be put into question, at least conditionally. This does not mean that the principles of Kumhof and Noone are unthinkable or flawed, but that one should try to find lighter solutions to the legitimate concerns regarding uncontrolled CBDC volumes. This is what the following section will aim at.

6. A two-tier remuneration system for CBDC

Kumhof and Noone (2018, 34) are well aware of the possibility to address CBDC's potential structural and cyclical bank disintermediation through applying unattractive and/or negative interest rates on CBDC. However, they are skeptical that the tool of negative interest rates will always be sufficiently effective in crisis times:

"any nascent increase in the demand for CBDC can be eliminated by a drop in the interest rate on CBDC. But there are potential limits if this requires a highly negative interest rate, and if further reductions of the interest rate below this level become politically difficult... Assume therefore a CBDC price rule where the central bank fixes the interest rate on CBDC at the lowest politically acceptable level, and assume that even at this penalty rate group A wants to convert deposits to CBDC at (almost) any price, perhaps because it is concerned about the solvency of banks..."

In this section, it is proposed to solve the problem of political acceptance of (temporarily) very low interest rates on CBDC by differentiating remuneration according to the amount of deposits held, i.e. "tiering". Actually, such reserve tiering systems have often been applied by central banks for the remuneration of deposits, and exactly for the purpose to control the total amount of deposits while being forthcoming towards moderate levels of deposits. Under such a system, a relatively attractive remuneration rate is applied up to some quantitative ceiling, while a lower interest rate is applied for amounts beyond the threshold. The Eurosystem has applied such tiering systems for deposit accounts of public sector institutions, notably of domestic government and foreign central banks or sovereign wealth funds. Regarding the remuneration of *government deposits*, for example, article 5 of the Eurosystem's DAIM guideline⁹ specifies that a two-tier system applies as follows:

1. *Remuneration of government deposits shall be subject to the following ceilings: (a) for overnight deposits, the unsecured overnight market rate; (b) for fixed term deposits, the secured market rate or, if not available, the unsecured overnight market rate.*
2. *On any calendar day, the total amount of overnight and fixed term deposits of all governments with an NCB exceeding the higher of either: (a) EUR 200 million; or (b) 0,04 % of the gross domestic product of the Member State in which the NCB is domiciled, shall be remunerated with an interest rate of zero per cent. If the deposit facility rate on this day is negative, then an interest rate no higher than the deposit facility rate shall apply.'*

⁹ GUIDELINE OF THE EUROPEAN CENTRAL BANK of 20 February 2014 on domestic asset and liability management operations by the national central banks (ECB/2014/9), as amended by GUIDELINE OF THE EUROPEAN CENTRAL BANK of 5 June 2014 amending Guideline ECB/2014/9 on domestic asset and liability management operations by the national central banks (ECB/2014/22)

Similarly, the Eurosystem reserve management services (ERMS¹⁰), granting accounts to foreign central banks and public sector funds, also typically foresee the differentiation between a more attractive rate applying up to some limit, and a less attractive one without limits. If the remuneration rate for tier two deposits is sufficiently unattractive, then the amount of such deposits should be low, or even zero. The central bank should also be able to counter, through an as aggressive as needed lowering of tier two remuneration rates, the inflow of additional deposits in a financial crisis context.

One may also note that some central banks (DK, SE, CH, JP) have collected experience over the last years with a differentiated remuneration of bank deposits with the central bank. For example, the Bank of Japan introduced on 29 January 2016 a three-tier system (Press release of the Bank of Japan dated 29 January 2016) following the existence of two-tier approaches in other central banks:

“The Bank will introduce a multiple-tier system which some central banks in Europe (e.g. the Swiss National Bank) have put in place. Specifically, it will adopt a three-tier system in which the outstanding balance of each financial institution's current account at the Bank will be divided into three tiers, to each of which a positive interest rate, a zero interest rate, or a negative interest rate will be applied, respectively.”

The size of the better remunerated tiers is calculated by the Bank of Japan for each bank essentially in proportion to the bank's required reserves, which itself are calculated proportionally to the short-term liabilities of the bank to non-banks. Even before that, a differentiated remuneration had been applied by many central banks for required and non-required reserves of banks with the central bank. For example, in the case of the Eurosystem, since the launch of the euro in 1999, *required* reserves were remunerated at the rate of the main refinancing operations, while *excess reserves* were remunerated at zero (and in addition, a deposit facility was offered which provided remuneration normally at 100 basis points below the rate of the main refinancing operation).

In sum: central banks have ample experience with tiered remuneration systems. These could be readily applied to deposit-based CBDC and could address the structural and the financial crises related bank disintermediation issues without exposing households using CBDC for payment purposes to (perceived) final repression. Of course, an undue structural or transitional increase in CBDC at the expense of banks could also be addressed by a single tier system in which the interest rate applied to the entire CBDC deposits would be sufficiently low (or temporarily lowered). However, a two-tier system seems to have important advantages:

- It allows assigning the **payment function of money to tier one CBDC**, while the **store of value function would be assigned to tier two**, and would essentially be dis-incentivized through an unattractive remuneration rate. Indeed, central bank money should probably not become a large-scale store of value, i.e. a major form of investment of households, as this eventually implies that the central bank would become an investment intermediary of the economy (for which it has no particular qualification).
- It ensures that **CBDC is attractive** to have in principle for all households, **as reliance on tier one CBDC never needs to be dis-incentivized by a particularly low remuneration rate**.
- A two-tier system allows **better steering of the amount of CBDC**, which provides additional confidence into the manageability of the introduction of CBDC.
- As mentioned above, it avoids that in a crisis situation, one would need to push into negative territory the remuneration of *all* CBDC. Thereby **tiering decisively reduces the scope for popular criticism of the central bank (e.g. of financial repression, expropriation of money holders, etc.)**. The central bank would need to communicate clearly at an early stage that the remuneration of

¹⁰ <https://www.ecb.europa.eu/paym/erms/html/index.en.html>

tier-two CBDC is not meant to be attractive, and may be made particularly unattractive in a crisis, as needed. For tier one CBDC, the central bank can commit to never charge negative rates.

The central bank can also provide a **commitment with regard to the quantity of tier one CBDC**. For example, it could promise to always provide per capita a tier one quota of e.g. EUR 3500, implying an amount of total tier one CBDC for households of around EUR 1.2 trillion (assuming an eligible euro area population of 340 million; the allowances of minors could be either set to zero or they could be allocated to a parent's CBDC account). To recall: banknotes in circulation in the euro area are somewhat above EUR 3500 per capita (summing up currently to around EUR 1.2 trillion); securities holdings of the Eurosystem (including both investment and policy portfolios) are currently around EUR 3 trillion; and the banking system has excess reserves close to EUR 2 trillion. Everything else unchanged, there would thus still be no need for large scale credit operations with banks if CBDC of a total amount of EUR 1 trillion would be issued now. The central bank could moreover commit to increase the tier one CBDC quota when the amount of banknote in circulation decreases. An amount of EUR 3500 for tier one CBDC could be interpreted as covering the average monthly net income of euro area households, such that the normal payment function of money would be covered. CBDC tier one allowances for companies would not necessarily have to be high, as it could be argued that the main objective of CBDC is to serve citizens. When estimating how tier one CBDC allowances would be translated into total CBDC volumes, it should on one side be taken into account that not all CBDC accounts will be opened rapidly, and maybe some households will never open an account, or will not hold the full tier one allowance on the account. On the other side, some households will be willing to hold tier two allowances.

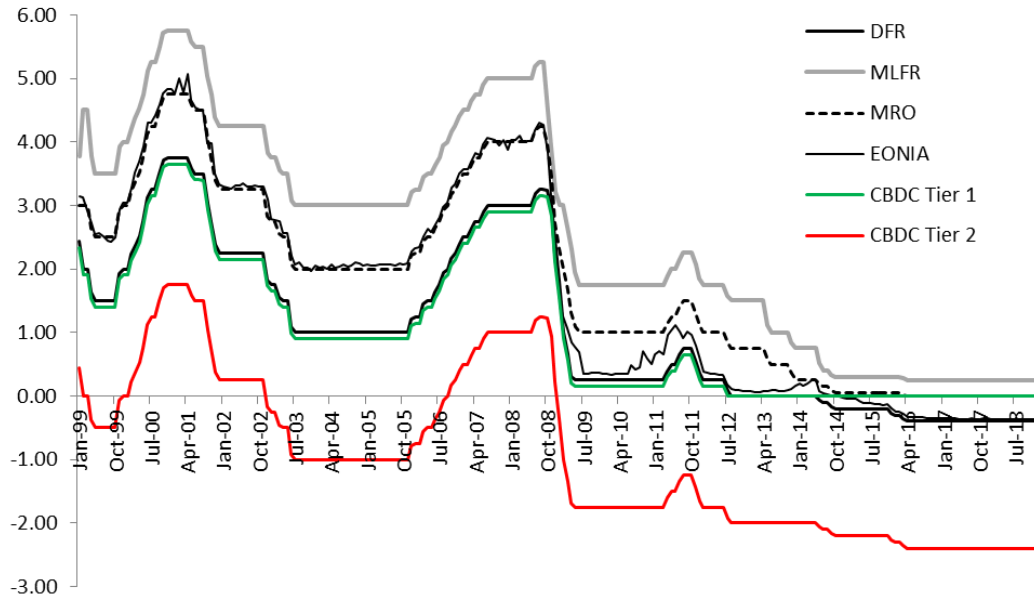
For corporates (financial non-banks and non-financials), the tier 1 allowance could be set to zero, or alternatively it could be calculated to be proportional to some measure of their size and thereby presumed payment needs. Simplicity and controllability of the assignments would be essential. If foreigners would be eligible to open accounts, then it may be recommendable that they would have a tier one ceiling of zero. Finally, a deposit based CBDC framework could in principle be complemented by an anonymous token-based CBDC. If so, then the anonymous token-based part would be remunerated at the same level as account-based tier two CBDC.

The tier 1 remuneration rate r_1 could be set in principle at a relatively attractive level, which could be the rate of remuneration of banks' excess reserves, and it would in addition be specified that it could never fall below zero. The tier 2 remuneration rate would be set such that tier 2 deposits are rather unattractive as store of value, i.e. less attractive than bank deposits or other short-term financial assets, even when taking into account risk premia. The two rates could co-move in parallel with policy interest rates, with in addition some special provision when the zero lower bound territory is approached. The rates would themselves not be regarded as policy rates. Moving the rates would simply serve keeping a similar spread over time to other central bank rates, and thus in principle to other market rates. The objective would be to sufficiently stabilize and control over time the incentives to hold CBDC. Of course, the existence of banknotes, which are invariably remunerated at zero, creates a variable spread between the remuneration of banknotes and CBDC, which may also have quantitative effects on both.

Initially, for example the following remuneration could be considered by the ECB for tier 1 CBDC: $r_1 = \max(i_{DFR}, 0)$, and for tier 2 CBDC: $r_2 = (i_{DFR} - 2\%)$. In words: r_1 would equal the rate of remuneration of excess reserves, with however a zero lower bound applying, while r_2 would be two percentage points below the remuneration of excess reserves, however without floor. An even less attractive option for tier 2 CBDC would be $r_2 = \min(0, i_{DFR} - 2\%)$. In this case, CBDC2 would be remunerated either like banknotes (as long as $DFR > 0$) or lower. In any case, a special downwards adjustment to the remuneration rate of CBDC would likely have been useful during the critical year after the Lehman default in 2008.

The following diagram compares for the period 1999 to 2018 how r_1 and r_2 (the latter in the first specification) would have compared to key ECB policy rates.

Figure 4: Fictitious example of interest rates on CBDC1 and CBDC for the last 20 years



The following table shows average, maximum and minimum monthly spreads between various relevant interest rates for the 19 years period January 2000 to end 2018:

Table 5: Historical spreads between CBDC remuneration rates and ECB and market rates, 2000-2018

	Average	Highest monthly average	Lowest monthly average
r_1 -DFR	0.08	0.40	0.00
r_2 -DFR	-2.00	-2.00	-2.00
r_1 -EONIA	-0.49	0.37	-1.31
r_2 -EONIA	-2.57	-2.03	-3.31
r_1 -HH ONR dep	0.46	2.33	-0.41
r_2 -HH ONR dep	-1.61	0.33	-2.51
r_1 -time dep < 2Y	-1.11	0.59	-3.23
r_2 -time dep < 2Y	-3.19	-1.41	-5.23
r_1 -Banknotes (0%)	1.09	3.75	0.00
r_2 -Banknotes (0%)	-0.99	1.75	-2.40

The relatively large difference between the minimum and maximum spread between CBDC rates and overnight household deposit rates, as well as the fluctuation between CBDC rates and the zero-remuneration rate of banknotes suggests that CBDC volumes (both tier one and tier two) could fluctuate somewhat as a consequence of varying spreads. Some fluctuation is acceptable, and should not cause particular financial stability risks. It should be noted that a high variability of spreads also applies to the remuneration of liquid investments (sight deposits, yields on liquid government bonds) relative to the remuneration of banknotes (at zero), without this having led to problematic fluctuations of banknote demand.

It would also not be a problem to add a **third tier to CBDC with an even lower remuneration**, if this is considered useful to achieve an optimal level of control of total CBDC quantities. For example, the second tier could be three times the first tier, the second tier's remuneration could always be kept at ($i_{DFR} - 2\%$), but the third tier could be remunerated very negatively, say at -3% in normal times, and in crisis times if needed at e.g. -10% . From a technological perspective, introducing another tier should not be an issue. Obviously, as long as banknotes exist, CBDC holders can transform badly remunerated CBDC into banknotes – but if they prefer banknotes to deposits with banks, then they can do so already today. Finally, as mentioned, a special remuneration rate could also apply to foreign CBDC depositors, i.e. outside the tiering system which would apply to domestic households and enterprises. At the end, the central bank could establish any matrix of remuneration rates, with one dimension of the matrix capturing the different types of holders, and the other the remuneration rates for the potentially many tiers. The additional complexity implied by such a matrix would be moderate. Of course, the ambitions of the matrix should remain humble: to sufficiently control the overall amount of CBDC while letting different types of entities benefit from it in a fair manner. Ideally, the matrix would be based on objective criteria, also to avoid criticism of parties that would feel treated unfavorably.

In sum: the central bank would have significant degrees of freedom to set the remuneration of tiered CBDC in a way to make CBDC both attractive and controllable, namely through:

- **Distinguishing an attractively remunerated first tier from a less attractively remunerated second tier** (and possibly even a third tier with an even worse remuneration, etc.).
- Choosing the **size of the tier one allowance per capita**. Taking the euro area as example, e.g. 1000, 3500, or 5000 euro would imply an amount of tier one CBDC of around 30%, 100%, and 140% of the current level of euro banknotes in circulation.
- Choosing the **remuneration rate of each tier**, and in particular of tier two, which could be either moderately or clearly unfavorable, whereby the latter case is of course most effective to be confident that CBDC volumes will not significantly exceed the total tier one CBDC allowance.
- **Reserve the right to do further adjustments on the remuneration rate of tier two** (and tier three, etc.) CBDC if needed, while **committing to never remunerate tier one CBDC negatively**.

7. Bank disintermediation with low-volume CBDC?

The attractiveness of CBDC for payment purposes does not only depend on the *amount* of CBDC that would be remunerated at a fairly attractive level, but also on other features of the use of CBDC as means of payment. It will matter in particular whether account services of CBDC include the services that deposit accounts with commercial banks typically offer, like remote internet access, mobile phones and cards, periodic payments to other accounts, debit orders, user-defined maximums for different types of transfers, etc. The ability to link the account with the accounts of broker-dealers which offer a full range of investment services will also be relevant. In any case, the central bank would presumably not offer other advanced banking services (foreign exchange transfers, FX operations, derivatives, etc.). There would therefore still be a difference relative to the breadth of services by commercial banks. The choice between an initially smaller or bigger difference may be driven also by considerations regarding the possible implications on commercial banks. In the long run, this should however not matter, i.e. if the provision of certain services is possible at low unit costs for CBDC accounts also because of the large number of accounts, then the central bank may conclude that it is legitimate to offer these services, even if it is in competition with commercial banks.

If the services offered by the central bank are relatively comprehensive, then, despite an effective control of the total amount of CBDC at a moderate level, still CBDC risks undermining the role of the banking system as a higher share of retail investors will be fine to combine a central bank account with

the services of a non-bank financial services firm, and no longer have any bank deposit account. In this case, the length of the central bank balance sheet may remain limited, but the length of the banks' balance sheet may decrease at the benefit of the non-bank financial intermediation through securities-brokers, insurance companies, and mutual funds.

The following system of financial accounts illustrates such a case in which the total quantity of CBDC is well controlled, but where nevertheless the banking system is disintermediated because its sight deposits services are no longer needed. The creation of CBDC is now assumed to be fully at the expense of banknote circulation only, such that it has no effects on financial accounts of banks (i.e. it is of type **CBDC1**). The variable **SUBST** captures the possible disintermediation of the banking system, in the sense that deposit taking institutions could lose clients, for the benefits of non-bank financial services providers. It is assumed that the benefitting non-bank financial firms would also take over a part of the loan business of banks, maybe focusing on securitizations of loans or syndicated loans, or financing of large-scale infrastructure projects etc. The corporate and government sectors are not again shown as they are assumed to be unaffected.

Figure 6: Impact on bank funding despite unchanged length of central bank balance sheet

Households, pension and investment funds, insurance companies			
Real Assets	20	Household Equity	40
Sight deposits	5 -SUBST	Bank loans	5
Savings + time deposits	4		
New non-bank intermediaries	+SUBST		
CBDC	+CBDC1		
Banknotes	1 -CBDC1		
Bank bonds	4 +S1		
Corporate/state bonds	7 -S1		
Equity	8		
New non-bank intermediaries			
Loans to corporates	+Subst/2	Household investments	+Subst
Corp/gvt bonds	+Subst/2		
Commercial Banks			
Loans to corporates	8 -Subst /2	Sight deposits	7 -Subst
Loans to government	2	Savings + time deposits	5
Loans to HH	5	Bonds issued	4
Corp/gvt bonds	5 -Subst /2	Equity	3
Central bank deposits	0	Central bank credit	1
Central Bank			
Credit to banks	1	Banknotes issued	1 -CBDC1
Corp/gvt bonds	0	Deposits of banks	0
		CBDC	CBDC1

To what extent would the disintermediation of banks and the shift of business towards non-bank financial intermediaries matter? This will also depend on the **differences between the regulatory treatment of commercial banks (deposit taking institutions) and other financial intermediaries**, since regulation creates a clear segregation between the two. The regulator would therefore have to see if any regulatory adjustments may be desirable to react to the changes of financial structure caused indirectly by CBDC (see also section 6 of Juks, 2018). Overall, it should be acknowledged that CBDC will be a further factor contributing to change in the financial system, and to some extent independently of the total nominal level of CBDC, and that this may include effects on the relative competitiveness of banks. However, (i) there are anyway various technological developments that are relevant in this respect

beyond CBDC; (ii) per se, change should not be seen as a problem, but as an opportunity. Legitimate worries would relate to disruptive change scenarios which may occur if the change is too rapid and/or an industry of systemic dimension and nature is anyway under stress and the additional change factor intensifies this stress in a decisive way.

8. Flow-of funds comparison of CBDC with private digital currencies

In this section we briefly compare the implications of CBDC on financial accounts with the ones of crypto-assets, stable coins and narrow bank digital currency.

Crypto-assets

According to ECB Crypto-Assets Task Force (2019, 3), crypto assets are an “asset recorded in digital form and enabled by the use of cryptography that is not and does not represent a financial claim on, or a liability of, any identifiable entity”. Moreover, according to this task force report (p. 3), “Crypto-assets do not fulfil the functions of money and, at the current stage, neither do they entail a tangible impact on the real economy nor have significant implications for monetary policy.” The global market capitalization of crypto-assets relative to euro area GDP has fluctuated since June 2017 between around 1% and around 5% (p. 11). As crypto-assets are neither a financial claim nor a financial liability, they per se do not affect the accounts of the financial sector. They only directly affect the accounts of the household / investment sector which holds and mines these commodity-like assets (we assume here for the sake of simplicity that the mining takes place directly by households). To the extent that “mining” consumes resources, crypto-assets appear (in the simplest representation) as an asset switch from real assets to crypto assets (**CRYPTO.A**). To the extent that the value of the crypto-assets exceeds the mining costs, it is a balance sheet lengthening for households matched by an increase of net wealth (**CRYPTO.B**).

Figure 7: Impact of crypto-asset on financial accounts

Households, pension and investment funds, insurance companies					
Real Assets	20	−CRYPTO.A	Household Equity	40	+CRYPTO.B
Sight deposits	5		Bank loans	5	
Savings + time deposits	4				
Crypto-assets		CRYPTO.A +CRYPTO.B			
Banknotes	1				
Bank bonds	4				
Corporate/state bonds	7				
Equity	8				

As noted in the task force report quoted above, crypto-assets are not particularly suitable as means of payment and store of value (as their value denominated in the unit of account fluctuates heavily). Therefore, they are not really in competition with banknotes or sight deposits with banks, and therefore also secondary effects on the financial system are expected to remain limited for the foreseeable future.

Stable coins backed by reserves

“Stable coins” are attempts to overcome the extreme volatility of existing crypto-assets by aiming at a stable value (denominated in some unit of account). There is quite some diversity in stable coins constructions, and “to the extent that they have an identified issuer, are not crypto-assets according to the definition used in this paper and might qualify as e-money under some national legislation” (ECB Crypto-Assets Task Force, 2019, 14). Recently, central bankers’ interest in stable coins increased, after Facebook announced its Libra stable coin project (see www.libra.org). As Libra is planned to be backed

fully by liquid and high-quality reserves, it could indeed be interpreted to go more in the direction of an e-money institution. Libra would be “stable” in the currency basket it will replicate, and not in a single currency. Also projects such that “Utility Settlement Coin” (USC) fall under the stable coin definition (see www.fnality.org).

Stable coins can be backed by reserves in the form of central bank deposits or in other forms (deposits with highly rated banks or short-term government securities – the vision of Libra). The financial accounts below illustrate both cases. As stable coins are much more suitable as means of payments than crypto-assets (if we assume that they are issued for general payment purposes), they would be expected to substitute banknotes and/or sight deposits with banks or both (similarly to CBDC). The Government and corporate accounts are not shown as they are expected not to be affected. **STC2** are the stable coin holdings that result from the substitution of sight deposits with banks, and **STC1** are those resulting from the substitution of banknotes. With regards to the case of backing with commercial bank money and government bills, we assume that the two forms of reserves have a share of α and $(1-\alpha)$, respectively. We also assume (for the sake of simplification) that the holdings of government debt by the stable coin vehicle are coming from former banks’ holdings (and not from household holdings).

Figure 8: Financial accounts representation of stable coin with reserves in the form of deposits held with commercial banks and in the form of government bonds (e.g. like envisaged by Libra)

Households, pension and investment funds, insurance companies			
Real Assets	20	Household Equity	40
Sight deposits	5 - STC2		
Savings + time deposits	4	Bank loans	5
STC	STC2+STC1		
Banknotes	1 - STC1		
Bank bonds	4		
Corporate/state bonds	7		
Equity	8		
Stable coin issuing vehicle			
Deposits with banks	$\alpha(\text{STC2}+\text{STC1})$	STC issued	STC2+STC1
Government bonds	$(1-\alpha)(\text{STC2}+\text{STC1})$		
Commercial Banks			
Loans to corporates	8	Sight deposits	7 - STC2
Loans to government	2	STC Deposits	$\alpha(\text{STC2}+\text{STC1})$
Loans to HH	5	Savings + time deposits	5
Corp/gvt bonds	$5 - (1-\alpha)(\text{STC2}+\text{STC1})$	Bonds issued	4
Central bank deposits	0	Equity	3
		Central bank credit	1 - STC1
Central Bank			
Credit to banks	1 - STC1	Banknotes issued	1 - STC1

Figure 9: Financial accounts representation of stable coin holds its reserves with the central bank

Households, pension and investment funds, insurance companies			
Real Assets	20	Household Equity	40
Sight deposits	5 - STC2		
Savings + time deposits	4	Bank loans	5
STC	STC2+STC1		
Banknotes	1 -STC1		
Bank bonds	4		
Corporate/state bonds	7		
Equity	8		
Stable coin issuing vehicle			
Deposits with CB	STC2+STC1	STC issued	STC2+STC1
Commercial Banks			
Loans to corporates	8	Sight deposits	7 -STC2
Loans to government	2	Savings + time deposits	5
Loans to HH	5	Bonds issued	4
Corp/gvt bonds	5	Equity	3
		Central bank credit	STC2
Central Bank			
Credit to banks	1+ STC2	Banknotes issued	1 -STC1
		Deposits of banks	0
		STC deposits	STC2+STC1

The Narrow Bank

A narrow bank is defined here as a bank which would have all the deposits it issues matched on the asset side with central bank deposits (see also Mancini-Griffoli et al, 2018, 13). Other assets (physical assets) would be financed with equity. The running costs and the remuneration of capital would be covered by a spread between the narrow bank deposit rates and the rates at which the central bank remunerates the reserves of banks. Such a narrow bank tried to establish itself in the US (www.tnbusa.com). Assume that narrow banks would issue “narrow bank digital currency” (NBDC) – how would they change the financial system? Actually the financial accounts representation is identical to a stable coin backed by central bank deposits (see above), whereby the role of the stable coin vehicle is taken over by the narrow bank (i.e. replace in the accounts “Stable coin issuing vehicle” by “Narrow bank”; “STC1” by “NBDC1”; “STC2” by “NBDC2”).

Comparison of private digital currency innovations with CBDC

The following table compares the balance sheet implications of the different schemes on the banking system, i.e. commercial banks and the central bank. We call **X1** the amount of new means of payments substituting banknotes and **X2** the amount of new means of payments substituting deposits with banks. Similarity in this table does not necessarily imply similarity in practice, as the success of different schemes may be very different, and thereby the actual size of X1 and X2. As mentioned, in the case of CBDC, a close control of the amounts issued is possible through a two-tiered remuneration system.

Table 6: summary of specific flows of funds for a single country across various new digital currencies

	CBDC	Crypto assets	STC backed by deposits and government bonds	STC backed by central bank deposits	Narrow bank
Sight deposits of households with banks	-X2	0	-X2	-X2	-X2
Length of central bank balance sheet	+X2	0	-X1	+X2	+X2
Central bank credit to banks	+X2	0	-X1	+X2	+X2

Actually, the financial accounts implications have similarities across forms of digital currencies, and in particular stable coins backed by central bank deposits (“STCCB”), NBDC and CBDC seem to have identical financial account implications. Of course, in practice, they will not necessarily be identical since the success of each and the implied volume and dislocation of the financial accounts may vary.

- *First*, the confidence of households into STCCB/NBDC schemes will not necessarily be the same as the confidence into CBDC. Theoretically, it could be possible that STCCB/NBDC benefits from high levels of trust, since the schemes would aim at avoiding any credit and liquidity risk. Fraud risk could probably be low, as the vehicles could operate easily in full transparency and emphasize and seek closest co-operation with regulatory authorities.
- *Second*, the efficiency of STCCB/NBDC might be higher or lower than CBDC. It could be higher as STCCB/NBDC could take the form of competing entities, i.e. the market mechanism could continue to apply, and the vehicles could be very innovative in offering retail payment solutions, or rely on a broad initial global customer basis, such as Libra. On the other side, a direct provision by the central bank could also benefit from substantial economies of scale, and would reduce costs relating to credibility-providing mechanisms (Klein and Leffler, 1981), regulatory compliance, equity, etc..
- *Third*, the remuneration rate of private digital currencies would be determined by the efficiency of competing issuing entities and the rate of remuneration of reserves (be they deposits with the central bank or a mixture of other high-quality assets). For example, Libra would, according to the Libra white paper, not be remunerated, implying normally a positive carry (seignorage), put potentially also a negative carry if global interest rates are very low and partially negative. The central bank may choose for CBDC in principle any remuneration formula, including tiering systems. In so far, CBDC allows for better control. The competitiveness of STCCB/NBDC would also depend on the operational framework applied by the central bank, notably whether it operates in a corridor or a floor system, with the latter being more favorable to NBDC. A corridor system with a sufficient spread (e.g. 100 basis points) between the market overnight target rate and the remuneration rate of reserves would reduce the competitiveness of STCCB/NBDC schemes relative to the case of a floor system in which market overnight rates would be close to the rate of remuneration of reserves.
- *Fourth*, the regulatory treatment of private digital currencies will matter, as it may constrain their operations or make them more costly.
- *Finally*, STCCB/NBDC schemes depend on the willingness of the central bank to grant the issuer access to central bank deposits. Only if the issuer comes along with a normal banking license, the central bank may anyway be obliged to allow it to deposit at standard conditions.

The **impact on financial accounts can be generalized to the case of two (or n) countries, whereby asymmetric cases are of particular interest.** For example, CBDC issued in one country may be also used extensively in another country. Or, a global stable coin (“Libra”) is invested only in reserves in a subset of the countries where it is used as means of payment. The annex illustrates these two cases in financial accounts, whereby the focus will be on the stable coins case in which the reserves are held in the form of

deposits with banks and government securities (as envisaged for Libra). Flows of funds in an international context will obviously also depend on the foreign exchange regime. Moreover, they will depend on what forms cross border exposures, such as central bank foreign reserves, will take (they can take the form of government debt, bank deposits, or deposits with the central bank). The annex considers both a flexible and a fixed exchange rate regime. In the former case, it is assumed that the banking system will have to enter net foreign exposures to counterbalance the capital flows associated with cross-border electronic money holdings. In a fixed rate regime, changes in central bank reserves would compensate the private sector capital flows, whereby we assume that the reserves are held in the form of bank deposits. These are just two specific assumptions, but they are sufficient to illustrate the issues and the logic of capturing the flows in systems of financial accounts. Of course, the flow of funds analysis can be refined and calibrated e.g. towards the composition of foreign reserves as actually observed. Table 7 summarizes the key flow of funds implications identified in the systems of accounts shown in the annex. The flows “X1” are again the ones relating to the substitution of banknotes into the new digital currency, while “X2” are those relating to the substitution of deposits with banks. The annex “.A” indicates that these are the flows originating from the financial asset re-allocation of the household in A-country, while “.B” are the flows originating from the household in B-country. The upper, blue part of the table covers elements of the financial accounts of A-country, while the lower, pink part covers B-country. The change of foreign reserves of the central bank is only relevant for B-country, and only in case of a fixed exchange rate regime. The last row covers exchange rate effects.

Table 7: summary of specific flows of funds for a single country across various new digital currencies

	CBDC Flexible exchange rates	CBDC Fixed exchange rates	Libra-style STC Flexible exchange rates	Libra-style STC Fixed exchange rates
A - Banks change of deposits	-X2.A	-X2.A -X1.B -X2.B	-X2.A	-X2.A
A - Length of CB balance sheet	+X2.A +X1.B +X2.B	+X2.A +X1.B +X2.B	-X1.A	-X1.A
A - CB credit to banks	+X2.A +X1.B +X2.B	+X2.A +X1.B +X2.B	-X1.A	-X1.A
B - Banks change of deposits	-X2.B	-X2.B	-X2.B	-X2.B
B - Length of CB balance sheet	-X1.B	-X1.B	-X1.B	-X1.B
B - CB credit to banks	-X1.B	+X2.B	-X1.B	+X2.B
B - CB change of foreign reserves		-X1.B -X2.B		-X1.B -X2.B
Impact on exchange rate	B-currency depreciates		B-currency depreciates	

The following observations from this analysis of the asymmetric international use of new digital forms of money can be highlighted:

- Banks lose a part of their **household deposits** in both countries and independently of the exchange rate regime. The loss corresponds to the deposits that households substitute into the new form of digital money. An additional loss arises to the banks in A-country (the country issuing the internationally used CBDC): there in addition **outflows of foreign central bank deposits** occur as the B-central bank sees its foreign reserves decline by the amount of A-country issued CBDC holdings of B-households (of course the assumption that all foreign reserves are in the form of deposits is a strong simplification).
- The **length of central bank balance sheets** declines in all cases by the value of banknotes substituted by the new digital currency – except for the central bank issuing the (internationally used) CBDC. The balance sheet of this central bank expands, independently of the FX regime.
- The **required reliance of banks on central bank credit** can increase or decrease. It increases strongest for the banks in the country in which an internationally used CBDC is used (regardless of the FX regime). It also increases, although to a lesser extent, in the B-country under a fixed

exchange rate regime, as there the loss of foreign reserves dominates the reduced amount of domestic banknotes. It decreases by the amount of domestic banknote substitution in the case of country B for CBDC and under flexible exchange rates, in case of both countries A and B for Libra-Style STC under flexible exchange rates, and in the case of Libra-style STC and fixed exchange rates for the A-country.

- **Foreign exchange reserves of the B central bank** decline in a fixed exchange rate system both for A-CBDC and for Libra-style STC by the amount of B-country holdings of the new digital currency.

9. Conclusions

This paper tried to further demystify CBDC, also by representing it in a simple system of financial accounts which allows capturing its flow of funds implications. Moreover, the paper revisited the question how to address the risk, rightly stressed in the literature, that CBDC could structurally, or cyclically (in relation to financial crises) disintermediate the banking system. A simpler and less innovative alternative to the approach of Noone and Kumhof (2018) is developed, which relies on a tiered remuneration of CBDC, in line with long-tested central bank logic and practice. To use the terminology of Basil Moore (1988), the approach proposed here may be considered a “horizontalist” one, which is more instinctive to central bank market operations practitioners, in contrast to the contingent “verticalist” elements foreseen in Kumhof and Noone (2018). It was at the same time acknowledged that the control of CBDC quantities is not equivalent to the control of the impact of CBDC on the financial system, since CBDC might be a catalyst for the further shrinkage of bank balance sheets at the benefit of non-bank intermediaries, in particular if CBDC accounts offer relatively comprehensive account services such that many households may no longer feel a need to have a bank deposit account.

As remarked by Carstens (2019, 10), central banks are not there to “put a brake on innovations just for the sake of it”, but to ensure that implications of major changes are well understood so “that innovations set the right course for the economy, for businesses, for citizens, for society as a whole”. From this perspective, this paper may suggest that central banks could be somewhat open to studying CBDC, although the overall business case and the precise risks to change the financial system in a disruptive way deserve further analysis. This conclusion seems similar to the one of Juks (2018), although Juks is less assertive on the tools to address possible unwarranted effects of the introduction of CBDC. The overall business case for CBDC will also still depend on preferences of households as money users and voters. In progressive countries, in which the demand for banknotes falls rapidly and in which electronic payments have become the normal, a business case for CBDC seems relatively plausible. The recent take up of attention devoted to stable coins or related projects such as Libra, and the similarity of financial accounts implications of stable coins to the ones of CBDC suggests that the discussions on CBDC should take place also in the context of such private electronic money innovations.

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Annex : International flow of fund implications of digital currencies

This annex illustrates the flow of funds implications of new digital currencies in the case of two countries whereby the digital currencies are asymmetric with regards to the two countries. The annex covers two types of digital money: CBDC issued by central bank in country A but also used by households in country B, and a global stable coin like Libra which however invests its reserves only in country A (although it is also used in country B). Flow of funds in an international context obviously depend on the foreign exchange regime. Moreover, they will depend on how the changes of cross border exposures (e.g. central bank foreign reserves can take the form of government debt, bank deposits, or deposits with the central bank). Here we assume first a flexible, then a fixed exchange rate regime. In the former case, we moreover assume that the banking system will have to enter net foreign exposures to counterbalance the capital flows associated with cross-border electronic money holdings. This will lead to a depreciation of the currency of country B. In a fixed rate regime, changes in central bank reserves would compensate the capital flows, whereby we assume that the reserves are held in the form of deposits with banks in the other country. These are just two specific cases, but they are sufficient to illustrate the issues and the logic of capturing the flows in systems of financial accounts. We do not show the corporate and government accounts as they are assumed to be unaffected. Country A accounts are shaded in blue, country B accounts in red, and global vehicles in yellow.

- Figure A.1 covers the case of CBDC in a flexible exchange rate regime
- Figure A.2 covers the case of CBDC in a fixed exchange rate regime
- Figure A.3 covers the case of a Libra-style stable coin in a flexible exchange rate regime
- Figure A.4 covers the case of a Libra-style stable coin in a fixed exchange rate regime

The impact on the length of bank and central bank balance sheets, and on the dependence of banks on central bank or cross-border funding, are summarized in a table in section 8 of the main text.

We still use the absolute numbers broadly reflecting the euro area (if they are interpreted as trillions of EUR) apply to each country, but this obviously could be changed.

Figure A.1: Financial accounts representation of CBDC, two country case, flexible exchange rates in which banking systems enter cross border claims and liabilities compensating the CBDC related capital flows

A - Households, pension and investment funds, insurance companies					
Real Assets	20		Household Equity	40	
Sight deposits	5	-CBDC2.A			
Savings + time deposits	4		Bank loans	5	
CBDC		+CBDC1.A +CBDC2.A			
Banknotes	1	-CBDC1.A			
Bank bonds	4				
Corporate/Government bonds	7				
Equity	8				
A- Commercial Banks					
Loans to corporates	8	-	Sight deposits	7	-CBDC2.A
Loans to government	2		Savings + time deposits	5	
Loans to HH	5		Bonds issued	4	
Corp/state bonds	5	-	Equity	3	
Central bank deposits	0		CB credit	1	+CBDC2.A +CBDC1.B +CBDC2.B
Claims on banks of country B		+CBDC1.B +CBDC2.B			

A - Central Bank			
Credit to banks	1	$+CBDC2.A + CBDC1.B + CBDC2.B$	
Corp/Government bonds	0		
Banknotes issued	1	$-CBDC1.A$	
Deposits of banks	0		
CBDC		$+CBDC1.A + CBDC2.A + CBDC1.B + CBDC2.B$	
B - Households, pension and investment funds, insurance companies			
Real Assets	20		
Sight deposits	5	$-CBDC2.B$	
Savings + time deposits	4		
CBDC		$+CBDC1.B + CBDC2.B$	
Banknotes	1	$-CBDC1.B$	
Bank bonds	4		
Corporate/Government bonds	7		
Equity	8		
Household Equity	40		
Bank loans	5		
B- Commercial Banks			
Loans to corporates	8	-	
Loans to government	2		
Loans to HH	5		
Corp/state bonds	5	-	
Sight deposits	7	$-CBDC2.B$	
Savings + time deposits	5		
Bonds issued	4		
Equity	3		
Central bank credit	1	$-CBDC1.B$	
Liabilities to banks of country B		$+CBDC1.B + CBDC2.B$	
B - Central Bank			
Credit to banks	1	$-CBDC1.B$	
Banknotes issued	1	$-CBDC1.B$	

Figure A.2: Financial accounts representation of CBDC, two country case, fixed exchange rates, foreign reserves in the form of deposits with banks (household accounts unchanged to previous figure)

A- Commercial Banks			
Loans to corporates	8		
Loans to government	2		
Loans to HH	5		
Corp/state bonds	5		
Central bank deposits	0		
Sight deposits	7	$-CBDC2.A$	
Savings + time deposits	5		
Bonds issued	4		
Equity	3		
CB credit	1	$+CBDC2.A + CBDC1.B + CBDC2.B$	
Deposits foreign CBs (change)		$-CBDC1.B - CBDC2.B$	
A - Central Bank			
Credit to banks	1	$+CBDC2.A + CBDC1.B + CBDC2.B$	
Banknotes issued	1	$-CBDC1$	
Deposits of banks	0		
CBDC		$+CBDC1.A + CBDC2.A + CBDC1.B + CBDC2.B$	
B- Commercial Banks			
Loans to corporates	8		
Loans to government	2		
Loans to HH	5		
Corp/state bonds	5		
Sight deposits	7	$-CBDC2.B$	
Savings + time deposits	5		
Bonds issued	4		
Equity	3		
Central bank credit	1	$+CBDC2.B$	
B - Central Bank			
FX reserves (change)		$-CBDC1.B - CBDC2.B$	
Credit to banks	1	$+CBDC2.B$	
Banknotes issued	1	$-CBDC1.B$	

Figure A.3 *Libra – two countries case – flexible exchange rates*

A - Households, pension and investment funds, insurance companies			
Real Assets	20	Household Equity	40
Sight deposits	5 - STC2.A		
Savings + time deposits	4	Bank loans	5
STC	STC2.A + STC1.A		
Banknotes	1 -STC1.A		
Bank bonds	4		
Corporate/state bonds	7		
Equity	8		
A - Commercial Banks			
Loans to corporates	8	Sight deposits	7 -STC2.A
Loans to government	2	STC Vehicle's Deposits	$\alpha(\text{STC1.A} + \text{STC1.B} + \text{STC2.A} + \text{STC2.B})$
Loans to HH	5	Savings + time deposits	5
Corp/gvt bonds	$5 - (1 - \alpha)(\text{STC1.A} + \text{STC1.B} + \text{STC2.A} + \text{STC2.B})$	Bonds issued	4
Central bank deposits	0	Equity	3
Claims to banks in country B	STC1.B + STC2.B	Central bank credit	1 -STC1.A
A - Central Bank			
Credit to banks	1 -STC1.A	Banknotes issued	1 -STC1.A
Global stable coin issuing vehicle – holding reserves only in A-Land			
Deposits with A-banks	$\alpha(\text{STC1.A} + \text{STC1.B} + \text{STC2.A} + \text{STC2.B})$	STC issued	STC1.A + STC1.B + STC2.A + STC2.B
Government bonds	$(1 - \alpha)(\text{STC1.A} + \text{STC1.B} + \text{STC2.A} + \text{STC2.B})$		
B - Households, pension and investment funds, insurance companies			
Real Assets	20	Household Equity	40
Sight deposits	5 - STC2.B		
Savings + time deposits	4	Bank loans	5
STC	STC2.B + STC1.B		
Banknotes	1 -STC1.B		
Bank bonds	4		
Corporate/state bonds	7		
Equity	8		
B - Commercial Banks			
Loans to corporates	8	Sight deposits	7 -STC2.B
Loans to government	2	Savings + time deposits	5
Loans to HH	5	Bonds issued	4
Corp/gvt bonds	5	Equity	3
Central bank deposits	0	Central bank credit	1 -STC1.B
		Liabilities to banks in A-land	STC1.B + STC2.B
B - Central Bank			
Credit to banks	1 -STC1.B	Banknotes issued	1 -STC1.B

Figure A.4 Libra – two countries case – fixed exchange rates

A - Commercial Banks			
Loans to corporates	8	Sight deposits	7 $-\text{STC2.A}$
Loans to government	2	STC Deposits	$\alpha(\text{STC1.A} + \text{STC1.B} + \text{STC2.A} + \text{STC2.B})$
Loans to HH	5	Savings + time deposits	5
Corp/gvt bonds	$5 - (1 - \alpha)(\text{STC1.A} + \text{STC1.B} + \text{STC2.A} + \text{STC2.B})$	Bonds issued	4
Central bank deposits	0	Equity	3
		Central bank credit	1 $-\text{STC1.A}$
		Liabilities to CB-A-(change)	$-\text{STC1.B} - \text{STC2.B}$
A - Central Bank			
Credit to banks	1 $-\text{STC1}$	Banknotes issued	1 $-\text{STC1}$
Global stable coin issuing vehicle – holding reserves only in A-Land			
Deposits with A-banks	$\alpha(\text{STC1.A} + \text{STC1.B} + \text{STC2.A} + \text{STC2.B})$	STC issued	$\text{STC1.A} + \text{STC1.B} + \text{STC2.A} + \text{STC2.B}$
Government bonds	$(1 - \alpha)(\text{STC1.A} + \text{STC1.B} + \text{STC2.A} + \text{STC2.B})$		
B - Commercial Banks			
Loans to corporates	8	Sight deposits	7 $-\text{STC2.B}$
Loans to government	2	Savings + time deposits	5
Loans to HH	5	Bonds issued	4
Corp/gvt bonds	5	Equity	3
Central bank deposits	0	Central bank credit	1 $+\text{STC2.B}$
B - Central Bank			
FX reserves (change)	$-\text{STC1.B} - \text{STC2.B}$	Banknotes issued	1 $-\text{STC1.B}$
Credit to banks	1 $+\text{STC2.B}$		