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Macro and Micro Implications of the introduction of Central Bank Digital Currencies: An Overview

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Abstract

After the emergence and widespread of cryptocurrencies central banks are studying how their digital currencies may favor the macroeconomic policy implementation. There are many challenges to this process both in legal and economic (financial, monetary) areas. The paper studies the potential movement from a two-tier banking system (central bank and banks) to a one-tier banking system in the case of CBDCs emission, including the issues of competition and commercial banking profitability. The more specific question is the change in the transmission of monetary policy with CBDC emission.

Keywords: CBDC, digital currency, cryptocurrency, monetary policy.

JEL: A10, B53, E40, E42, E44

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1. Introduction

In modern economies, commercial banks create the largest part of the money through credit emission under the control of the central bank as lender of last resort (McLeay, Radia and Thomas, (2014 a, b), Werner (2014), Werner (2016)). However, since the beginning of the 2010s, the emergence and the spread of private cryptocurrencies[4] has a potential to undermine this scheme. Indeed, private cryptocurrencies and crypto assets constitute the perfect antithesis to the commercial banks' money creation. In their purest versions, cryptocurrencies are created in a decentralized way based on peer-to-peer relationships without the intermediation of banks. It follows that, potentially, cryptocurrencies escape any ex-ante and ex-post, direct or indirect control of commercial banks and monetary authorities (Central Banks and governments). Hence, following the nature and type of a cryptocurrency, its quantity may increase automatically (through the level of transaction and as a percentage of the remuneration of the agents that validate the transaction blocks as with Bitcoins). Potentially, both this constant increase and the anarchic development of crypto-assets networks could challenge and jeopardize the stability of the monetary and financial market. Indeed, by resorting to parallel currencies, the economic agents could overcome any credit constraint and may threaten the central bank's monetary policy credibility.

Cryptocurrencies favor an absolute decentralized creation scheme as bitcoin's creator, Satoshi Nakamoto showed it in his famous 2008's paper. Satoshi advocates for free-issuing money systems that spread out of the sphere of the contemporary institutional banking system.

[4] Literature does not provide a single and unified definition of a cryptocurrency. For example, the Bank for International Settlements (BIS) identifies a "virtual currency"[4], a "digital currency" and a "cryptocurrency" (see (BIS, CPMI, November 2015), (BIS, CPMI, March 2018)), and for BIS these three terms are in fact the same. The BIS perceives cryptocurrency as an asset with a number of unique characteristics. BIS defines a "digital currency" through the following key characteristics: i) Issued only electronically, ii) Not issued in national currencies and not associated with them, iii) Not a claim of anyone (as opposite to traditional money), iv) Has zero intrinsic value, that is, does not generate a stream of payments, v) Used for peer-to-peer exchange, i.e. direct exchange between participants of the (payment) system using distributed registry technology (blockchain), vi) Is an asset that has borne some characteristics of money (in particular, is a means of payment).
Thus, furthermore, it is noteworthy that the BIS talks about digital currencies as potential substitutes for e-money. The European Central Bank (ECB) (see (ECB, February 2015)) defines a cryptocurrency as a "decentralized virtual currency scheme". At the same time, virtual currency is defined as "a digital representation of value, not issued by a central bank, credit institution or e-money institution, which in some circumstances can be used as an alternative to money". Virtual currency schemes are a term "used to describe both the aspect of value (i.e. virtual currency) and that of the inherent or in-built mechanisms ensuring that value can be transferred". The International Monetary Fund (IMF) does not give a strict definition of a cryptocurrency. However, according to the IMF's interpretation (see (IMF, June 2018)), cryptocurrencies are not currencies, but rather assets investing in which is highly risky.

By extension, conceived as a peer-to-peer currency based on Distributed Ledger Technologies (DLT)), bitcoin leads to the decentralization of money creation. This process is supposed to be competitive and more efficient than the contemporary credit system founded on a network of commercial banks that the central bank regulates as a lender of last resort. Both libertarian and neo-Austrian economists joined this view and advocate for an end of central banks' monopoly[5]. The arguments justifying DLT technologies are that they allow constant solvency checking between agents engaged in electronic transactions. This means the undermine of of trust in the commercial banks as third-party intermediation in the payment process. This approach took sense after the financial and monetary crash of 2007-2008. Indeed, crypto assets supporters consider that using blockchain ensures transparent, open and traceable exchange, a prerequisite for guaranteeing a direct democracy among internet users. A macroeconomic argument suggests that Bitcoin economy would implement a variant of Milton Friedman's monetary policy (see Friedman (1960, p. 90)) i.e. a ""*k-percent rule" of emission that could help to control the rising of prices and thus, the inflation/deflation process."* (Bohm and al. 2015, p. 233-234).

Potentially, central banks could face a major challenge if the cryptocurrencies expansion prevents them from protecting the core and the motives of their creation and existence: price stability and reliability of the monetary and financial systems. In all cases, central banks play an important role in the regulation process and their responsibility is divided into three major policy objectives:

- Ensuring that money works as a convenient and efficient medium of exchange. This means that central banks oversee the payment system,

- Guaranteeing the financial stability of the economy by maintaining money as a stable store of value.

- Warranting monetary stability by maintaining the currency as a stable unit of account and limiting inflation.

It follows that the central bank's management is highly centralized and, traditionally, it uses three main instruments: open market operations, discount rate policy and reserve-

[5] It is important to see that in the virtual library of the Nakomoto's Institute, most referred economic papers and books are related to these streams of thought with a special mention to Hayek's views on money. https://nakamotoinstitute.org/literature.

requirements policy. In determining its monetary policy, the central bank directly these instruments or policy variables under its control.

Despite their first reluctant reaction to the cryptocurrency phenomenon, monetary authorities of most countries very well understood that a *status quo* situation may not last. Indeed, most monetary and financial organizations and authorities consider that, sooner or later, if left without control, the expansion of crypto instruments may become irreversible and could endanger the payment and financial systems. For instance, the International Monetary Fund (IMF) Chair considers that crypto-assets could constitute a credible alternative to cover the potential risk of payment crisis due to the massive indebtedness of world economies: "*That is why policymakers should keep an open mind and work toward an even-handed regulatory framework that minimizes risks while allowing the creative process to bear fruit*", Lagarde (2018). Furthermore, structural changes in people's payment and investment habits make the Central Bank Authorities integrate the blockchain technologies in the structural organization of national payment systems.

Concerning the cryptocurrencies phenomenon, some central banks are actively developing electronic payments called "Central Bank Digital Currencies" (CBDC) that comprise not only traditional electronic currencies (as electronic credit transfers) but also cryptocurrencies based on DLT, understood as "Central Bank Cryptocurrencies" (CBCC). Indeed, CBDC or CBCC could help conduct not only wholesale operations (that include clearing and settlement operations) but also retail operations - i.e. the use of central bank digital currencies by non-bank agents for their current transactions. It means the necessity to reconsider the relationships between the central bank and commercial banks because CBDCs' extension may threaten their traditional payments function.

Hence, the introduction of cryptocurrencies raises many questions about their impact on the regulation of the money creation, the efficiency of the monetary policy, the role of the present and the future of the commercial banks, the status of the central banks. To answer these questions it`s necessary to analyze both theory and practice.

The purpose of this article is mainly methodological and deals with the way of CBDC may be enforced, the consequences, first, for the private banking system and, second, for the monetary policy. Indeed, CBDC introduction is not an easy task from technical and theoretical viewpoints. Technically, the decision-makers have to choose what kind of CBDC to implement. For instance, it is easier to confine them in the area of inter-banks clearing operation than to

expand them to retail payments between non-banks agents. And, once a Central Bank chooses to open them to the public it`s necessary to decide on how to do it.

The first point that this paper deals with is understanding the consequences of the CBDC introduction for the commercial banks' activity. Indeed, public CBDCs directly challenge payment system. Substituting commercial bank money to CBDC payments can lead to payments system destabilization and affect economic activity. Another possible effect concerns the limitation of the sphere of activity of commercial banks which could lose their leading role in the creation of money. The degree of CBDCs use to firms and individuals is also an open question.

If central banks can efficiently replace the commercial banks in their payment activity without negatively impacting the economy, then the question of the effectiveness of monetary policy can be raised.

The paper is built as follows. Section two aims at understanding the specificity of CBDCs and their central bank money feature. The consequences of their introduction to the commercial bank system are discussed in section three. We focus then on the theoretical approaches that define the conditions for the coexistence of bank money and CBDC circulation. The fourth section is devoted to a macroeconomic approach to monetary policy, while the fifth section concludes.

2. CBDCs: monetary authorities' motivation and emission design

There is no one concrete CBDC definition in the literature. At first stages digital currencies that could be potentially issued by monetary authorities were named "central bank cryptocurrencies" (CBCC), meaning that they are just like "cryptocurrencies" but with a central issuer. In (Bech, Garatt, 2017) report we can find that "*CBCC is an electronic form of central bank money that can be exchanged in a decentralized manner known as peer-to-peer, meaning that transactions occur directly between the payer and the payee without the need for a central intermediary*." Bjerg (2017) stresses one more CBCC feature: universal accessibility, i.e. it can be easily obtained and used to make payments. Later BIS (2018) started using the term "*central bank digital currencies*" instead of "central bank cryptocurrencies" to emphasize that unlike cryptocurrencies that are not a claim on anyone (as opposed to traditional money), central bank digital currencies are a claim on CB like cash or reserves. In this report, BIS also indicates the lack of a clear definition and speaks about CBDCs as a new type of central bank money denominated in the existing units of account that serves as a means of payment and a store of value. According to BIS (2018), "*a CBDC is a digital form of central bank money that is*

different from balances in traditional reserve or settlement accounts". According to the International Monetary Fund (Mancini-Griffoli, Tommaso, et al., 2018), CBDC "*would be a widely accessible digital form of fiat money, intended as legal tender. One day, it could fully replace physical cash. CBDC seems to be a natural next step in the evolution of official coinage (from metal-based money, to metal-backed banknotes, to physical fiat money)*". So, CBDCs is a new form of electronic liabilities of the central bank that can be used as a means of payment and a store of value.

Thus, it`s important to understand monetary authorities' motivation to develop their digital currencies.

- First, the growing interest of economic agents in the so-called private digital coins (tokens, cryptocurrencies) can be explained by the specific features of CCs; pseudonimity, lack of central regulator and (global) legal norms and standards, 24/7 availability for making transactions, potentially high returns, etc.
- Second, the emergence of new players in the provision of payment services and intermediation (cryptocurrency payment systems like Bitcoin, Ripple, Stellar). This is accompanied by the growing interest from the financial sector in technological innovations. That is why the refusal to issue CBDCs may lead to the gradual replacement of central bank money by private tokens.
- Third, the continued decline in the demand for cash in several countries is also named as a reason for central banks to issue their digital currencies, because such a decrease may lead to the lack of public access to the claims of the central bank. Bech et al. (2018) have shown that during 2007-2016 the demand for cash (% of GDP) has decreased significantly in Sweden.[6] Skingsley (2016) and Sveriges Riksbank (2017) suppose that CBDCs can become an alternative to cash if agents avoid it. The problem in the case of Sweden also arises from the fact that Riksbank does not pay interest on commercial banks' reserves. It provokes the risk that public demand for CB money may disappear in the nearest future. However, as was shown by Woodford (2000), monetary policy can remain effective even with zero demand for cash if the central bank can affect the level of money market interest rate[7].

[6] Authors also analyzed Japan, China, the EU, the USA, Australia, Canada, and Great Britain.

[7] However, this view of decreasing demand for cash is challenged by converse opinions. For instance, Berentsen and Schär (2018) note that the demand for cash in Switzerland has increased since the crisis in 2008 and, then, it is far from declining. Indeed, the Swiss currency is a strong store of value against the potential insolvency of financial institutions. This trend of the growth in cash demand may be seen also in large countries like the USA. Indeed, Judson (2018) assesses the evolution of banknote demand, by denomination groups, for U.S. dollars as well as other currencies. She finds that large-denomination banknotes constitute most banknotes in circulation

There are two possible types of CBDCs: retail (or general-purpose) and wholesale. Retail CBDCs can be issued in two forms: in the form of tokens and serve as a cash equivalent for general purposes, and in the form of electronic money of individuals on central bank accounts (the idea goes back to (Tobin, 1985)). Wholesale CBDCs are an analog of reserves and are designed for making payments by financial institutions. There is no common understanding and representation of how CBDCs function. *One* possible way is that CBDCs can circulate in the same way as cash. The central bank can issue a CBDC and further turnover of CBDCs between banks, firms and consumers *may* be carried out without the Central Bank.

Thus, CBDCs are a new form of electronic account that is based on new technology. Nowadays commercial banks and central banks already exchange digital money. The potential major change is that CBDCs ~~will~~ could be issued by the central bank and used directly by customers and firms, and commercial banks will be outside of this framework. It means that the economy will move from the current monetary system to a new system where the banking system and the central bank compete.

CBDCs can have many characteristics (also inherent to monies and/or assets) that will affect their role in a payment system, financial system, and monetary policy (see table 1). These characteristics will affect the demand for CBDC and the degree of their attractiveness to economic agents.

not only in the United States, but also in countries that use cash intensively (Japan, India) or on the contrary, in countries with decreasing cash-use like Sweden. Maybe, the main factors that explain why monetary authorities and governments favor noncash transactions is the necessity to fight criminal activities (money laundering, tax evasion, drug and weapon traffics, etc.). Another factor is that economic agents consider cash to be a protection against negative interest rates (e.g. see Popper, Gates, and Almukhtar, (2017) in the New York Time).

Table 1 – Key design features of central bank money and their influence on the demand for CBDCs

Features	Existing central bank money		CBDCs			Influence on demand for CBDC if the latter is characterized by the "feature"[8]
	Cash	Reserves and settlement balances	General purpose		Wholesale	
			token	accounts	only tokens	
24/7 availability	Yes	No	Yes	?	?	Increases
Anonymity vis-à-vis central bank	Yes	No	?	No	?	
Peer-to-peer transfer	Yes	No	?	No	?	
Interest-bearing	No	?	?	?	?	
Quantitative limits on the use or holdings of CBDC	No	No	?	?	?	Decreases

Note: Yes = existing or likely feature? = possible feature, No = not typical or possible feature.

Source: (BIS, March 2018) and authors.

[8] Hereinafter *ceteris paribus*.

At first sight, CBDC emission could offer several potential benefits to modern economies.

The first one is diminishing criminal activities because all transactions are recorded in the system and fighting tax evasion.

The second benefit is that the use of the new technology based on P2P transactions may reduce the number of intermediaries and commissions. However, it is not obvious whether disintermediation may increase efficiency (taking the whole economy into consideration) because financial intermediaries help agents to match each other needs.

The third one is that CBDCs increase the financial inclusion of agents. It is true for agents who live in an advanced technological environment but do not have access to bank accounts[9]. However, in countries where agents have neither access to banking services nor to internet networks, CBCDs emission is unlikely to improve the situation.

The fourth advantage is that CBDCs may improve the payment systems efficiency by reducing transaction costs, liquidity and collateral requirements, and the settlement costs of transactions. However, there exist credit, liquidity, settlement and operational risks in wholesale CBDC payment systems like in traditional wholesale payment systems that use reserves to settle transactions. The interrelation of these risks in payment systems based on CBDCs is currently unknown and may differ significantly from the distribution of risks in traditional payment systems. Minimization/optimization of risks (trade-off) will depend greatly on the chosen technical solutions for making payments (emission "protocols", intraday liquidity policy, paying interest on CBDCs and so on).

In a conventional settlement system, all participating banks must be connected to central operators (clearinghouses and central banks) to settle their transactions. A central operator represents a single point of failure in this closed-loop system (systemic risk). If DLT is a way to achieve connectivity between agents, the systemic risk can be decreased. Although transaction mechanisms could be replaced by DLT, the role of a central operator remains a question to be answered. According to Project Ubin (2017) research, DLT offers the potential to improve domestic securities transactions, offering Delivery-vs-Payment (DvP) settlement in cases where it is not already available; significantly improve cross-border payments (Payment-vs-Payment) and securities transactions (DvP).

Furthermore, CBDCs may also improve the sustainability of retail payment systems. In case of a bank transfer failure, agents will have an alternative payment opportunity. The new

[9] According to FDIC, approximately 6.5 percent of U.S. households were unbanked or did not have a primary bank account, in 2017.

payment system may potentially reduce the concentration of liquidity and credit risk (Dyson and Hodgson, 2016)).

3. CBDC and Commercial banks

The mutual influence of CBDCs and commercial banks begins to be analytically and theoretically studied by contemporary literature. This analysis is of the utmost importance because both the near and distant future of commercial banks may become questionable in case of CDBCs retail operations. The fundamental reason for that stems from the different nature of commercial banks' "money" vs CBDCs. Indeed, CBDC payments have immediate debt discharging effect. Hence, the potential public access to CBDC, instead of confining it to the intra-bank transactions, involves a change in the agents' payment habits and needs. In this case the whole payment system (including central bank) should develop new institutional rules about credit and payments.

However, there is no consensus among decision-makers, bankers, and academics about the consequences of CBDC emission. Current researches do not draw clear conclusions. Indeed, the studies differ not only in methodology, models and their specific assumptions but also in set of the CBDCs that should be considered. In this section, we focus on some models that address the consequences of the introduction of CBDCs for the private banking sector.

CBDC emission could be a serious threat to the existing two-tier banking system. According to (Roubini, 2018), the main problem of CBDCs is that they would disrupt the current monetary system where commercial banks create credit money. If the public prefers CBDCs to commercial bank money, this leads to a decrease in the demand for bank deposits, which may cause the growth of deposit rates and the increase in price spreads between active and passive banking operations. This can force commercial banks to participate in more risky projects. An overall decrease in credit provided to the private sector will stimulate firms to finance their activities in the financial market through a bond or equity emission. So, CBDC emission can affect the structure of existing financial markets.

However, in the extreme case of the transfer of all private bank deposits to CBDCs, traditional banks would become "loanable funds intermediaries". This means that they will borrow long-term funds to finance long-term loans such as mortgages. For sure no central bank would prefer such a situation, because it would entail radical disintermediation of the private banking sector. Lagarde (2018) has advocated a solution to this problem: private-public partnerships between central banks and private banks. "*Individuals could hold regular deposits*

with financial firms, but transactions would ultimately get settled in digital currency between firms… Similar to what happens today, but in a split second.". The advantage of this procedure is that payments "*would be immediate, safe, cheap, and potentially semi-anonymous*". One alternative would be for central banks to lend back to private banks the deposits that moved to CBDCs. But if the government is the only provider of funds, the risk of state interference in lending decisions becomes obvious.

According to (Mancini-Griffoli, 2018), retail CBDCs would represent an alternative option for bank deposits for those that want to keep risk-free transactional balances. Therefore, any increase in the interest rate paid on CBDCs should be matched by an equal change in the rate paid on deposits, otherwise people would move their balances to CBDCs. It leads to new challenges and requirements for commercial banks: they have to react instantly and adjust deposits' interest rate flexibly in order not to cause bank runs. BIS (2018) cautioned that making electronic central bank money widely available could create a significant threat to the financial system. If the public gets direct access to the digital currency, economic agents will run to the central bank in times of panic, creating a "digital run" from private banks to the state. If the digital money is issued by one of the major central banks, this could even lead to cross-border panics and contagion as capital will move from riskier assets and financial institutions in countries experiencing turmoil into state-backed cryptocurrencies elsewhere. According to BIS research by (Barontini and Holden, 2019), different speed of digital currency emission could create "*a potential risk for spillover effects across borders*".

So, there are several possible directions of CBDC development and they depend on the scope of CBDC emission (full or partial replacement of the commercial banks payment activities), the relationship between the Central Bank and the commercial banks, the reaction of commercial banks to the growing role of CDBCs in the current payment activities etc.

There is no unified theoretical view regarding the implications of CBDCs emission for the commercial banking sector. Some authors consider that, whatever the way CBDCs enter the economy they have either a positive impact on the activity (Barrdear and Kumhof (2016)), or, potentially, are neutral under usual assumptions of perfect markets (Brunnermeier and Niepelt (2019)). Others follow the popular idea that CBDCs could make the financial and payment systems highly unstable or deeply challenge the banks' activity (for example, see Siciliani (2019)). To analyze this issue, we will discuss both views found in the literature.

3.1 CBDCs and Commercial banks: the condition for a harmonious co-existence

The Bank of England's researchers were among the first to discuss the potential extension of central bank digital currency on a larger scale than the usual clearing operations. Barrdear and Kumhof (2016) constructed a DSGE model to see how CBDCs could help to void monetary and financial crises of the 2008's type and how CBDCs could help to increase GDP. Authors apply this model to the USA data before the 2008 crisis and find that GDP could grow up to 3% through reducing real interest rates due to the introduction of CBDCs. Following their model, they distinguish a transitional period where CBDCs are channeled through an exchange of government bonds for CBDCs, then, in a "business as usual" setup, the public may access CBDCs directly and exchange their bank money for CBDCs.

They conceive CBDCs as essentially issued by the central bank that grants universal, electronic, 24x7, national-currency-denominated access to its balance sheet, and this asset is interest-bearing as well. In the authors' view, this new asset does not compete with commercial banks' deposits because the majority of transaction balances would continue to be held in the form of deposits within commercial banks that create credit money in "a credit makes deposits" scheme. Following their scheme, CBDCs present no danger to the banking system. It is only a way to smooth interest rates and secure financial and monetary activities. Authors perceive it as a diversification instrument that makes the whole payment system safer by supplying new form of central bank money.

Brunnermeier and Niepelt (2019a, b) consider that CBDCs renew the old controversies about the extension of payment activities to central banks from commercial banks. This is called the Chicago Plan initiated by Knight et al. (1933) or Fisher (1935, 1936). The debate was about extending or limiting the centralized control of banks and they concluded in favor of central banks.

Brunnermeier and Niepelt (2018) define conditions under which the emission of inside money (i.e. CBDCs) and outside money (credit bank money) are equivalent, even if inside money and outside money have liquidity or return differences. This means that CBDCs emission does not influence the equilibrium macroeconomic variables. Brunnermeier and Niepelt (2019 a) build a model that attempts to make equivalent the use of public money (central bank money) and private debt issued as money (bank credit money). They show that under specific conditions, the change of public against private money does not alter the private agents'

choice sets. This means, that the wealth of individuals and their equilibrium portfolios do not change and this equivalence between portfolios is made through changes in the price of money.

It follows that, before and after the exchange, the optimal choices and the equilibrium allocations remain the same. What are the conditions for neutrality? The swap must occur in the form of open-market operations, possibly augmented by contingent transfers to accommodate the effects of the swap on subsequent portfolio payoffs. Putting otherwise, the banks affected by the open-market operation should be compensated. Indeed, in case of a massive swap from bank deposits to a CBDC, the banks would lose a source of funding. But, as the central bank gains resources, it must invest these funds. The best way is then to replenish the commercial bank's accounts by lending them back these amounts. When the swap between deposits and CBDC does not present any risk, i.e. the central bank does not question banks' activity, this operation does not need compensation. In case the central bank questions the commercial banks' reliability, transfers are necessary to ensure the payoffs on households' and firms' portfolios are at the same level. Households and businesses, therefore, pay the central bank when deposits are poorly remunerated, (for example under a banking cycle) and receive payments in "normal" times when the return on deposits exceeds that of CBDCs.

This view is shared by Andolfatto (2018) through the modeling of a monopolistic banking sector in a deterministic overlapping generation (OLG) economy where he shows that introducing interest-bearing CBDCs promotes their financial insertion by facilitating the switch from cash money towards CBDCs. In this model, introduction of CBDCs challenges the monopolistic bank sector. However, this has no effect on bank lending rates and activity, but the monopoly's profit is reduced. Andolfatto shows that CBDC creation increases both the market deposit rate and expands the deposit base which leads to the reduction in the bank monopoly profits. In this specific model, it appears that CBDCs do not affect the level of bank intermediation that remains the same. However, the model is based on very strict assumptions. For instance, there is neither room for risk and moral hazard nor for competitive banks. It seems that the level of activity is unchanged, because CBDC has no-impact on the lending operation and, then, on the whole activity.

3.2 CBDC and commercial banks' activity destabilization

Another trend of literature considers that, conversely to the above developments, introduction of CBDCs may involve detrimental effects for commercial banks. Kim and Kwon (2019) study the implications of central bank digital currency for monetary stability. They consider a monetary general equilibrium model in which, first, banks provide liquidity in the

form of fiat currency, and, second, commercial bank deposits compete with central bank deposits in the CBDC account. For them, CBDC is an interest-bearing and account-based claim on the central bank. Private agents (firms and individuals) may access CBDCs via direct deposit at the central bank. It is important to note that for Kim and Kwon (2019) as CDBCs compete with the usual credit money of commercial banks, CBDCs have the advantage to immediately free a debt-owner. Indeed, as CBDC is a fiat-money, it works in the economy as cash. Then, a transfer of private deposits into the CBDC account essentially decreases the supply of private credit by commercial banks. Then, to remain competitive, commercial banks must raise the nominal interest rate. In turn, these factors lower the commercial banks' reserve-deposit ratio. Consequently, this decreased access to bank money may increase the likelihood of bank panic. Indeed, the commercial banks run the risk of becoming short of cash reserves to pay out to depositors. In Kim and Kwon (2019)'s opinion, if a central bank can lend deposits in CBDC account to commercial banks, then, this becomes equivalent to holding central bank reserves. It follows that this allows banks to increase their credit money supply. As a result, commercial banks' financial stability can be improved because the general increase of means of payment lowers nominal interest rate.

It follows that the financial and payment systems stability highly depends on the CBDC design and commercial banks' access to them. Siciliani (2019) considers that substitutes for commercial banks' personal current and saving accounts pose potential threats to the mainstream business model of commercial banks. His paper analyses the competition outcome between the bank and non-bank operators. Through a two-sided platform framework, he models the strategic interaction between different payment systems. In particular, the model focuses on the pricing strategies of a bank and its competitor to engage both parties (consumers and merchants who participate in a payment system) based on the theory of network's externalities.

Hence, the agents' utility on either side depends on their expectations regarding the number of agents on the other side. When satisfied, these expectations generate cross-group network benefits that are fortified by membership externalities (Armstrong, 2006), whereby agents on either side value the ability to make a payment to agents on the opposite side. Externalities are generated by the agents' failure to internalize the fact that their decision to join the network will make it more compelling for agents on the opposite side to do the same. Technically, Siciliani (2019) designs consumers' preference heterogeneity in two ways: consumers with high deposit balance and those with small ones. Then, he assumes that both have heterogeneous brand preferences which he models using the Hotelling's framework.

The results show that under undifferentiated platforms pricing competition is strong and only one platform will remain active, usually the incumbent bank. However, its position is worse than before the competition. When agents have the possibility to use either one platform or the other then this bank may keep away the non-bank operator's threat, competition is lower especially when the distribution of deposits skews towards a majority of depositors with small balances. Interoperability favors the incumbent bank when consumers value the ability to make payments particularly strongly (i.e., compared to the remuneration of deposits). In brief, banks could be exposed to a large deposit outflow as a result of the entry of a new platform, especially if the new entrant relies on access to the central bank's balance sheet. However, this effect can be mitigated by the presence of demand-side frictions. Finally, for Siciliani, platforms coexistence is facilitated when banks are willing to unify payments across them, or when public intervention imposes interoperability in the absence of cooperation.

The use of traditional central bank money is limited. These limits are essentially based on characteristics of money (metal or paper (banknotes)) that involve storage costs, security (forgery), handling etc. When central bank money becomes digital, the limits are mainly the customs or habits that bound its use to inter-banks operations. However, if bankers overcome these psychological or sociological habits, nothing prevents people from using central bank money to make retail payments as in the past merchants paid their customers, workers in gold, silver or copper coins. However, nowadays things are not so simple. Granting access to CBDC for retail operations may have consequences for the commercial bank's activity and the whole economy growth and stability.

In conclusion, the above theoretical approaches show that researchers are far from reaching a consensus in understanding the consequences of the introduction of CBCDs. Obviously, there are few studies to cover the whole field. Indeed, this review of papers shows that these contributions deeply diverge in methodology because they are built on different foundations (sectorial competition models, general equilibrium, intergenerational approaches, etc.). Models address specific situations, and each involves different views about the nature of CBDCs. Then, facing the contradictory results of sub-section one and two, the CDBC introduction and its consequence on the commercial banks system call for more specific studies before drawing definitive answers.

4. CBDC implications for monetary policy and banking system

There are concerns in the literature about the fact that CBDC emission can affect monetary policy transmission channels. However, according to (Mancini-Griffoli, 2018), the introduction of CBDC is unlikely to significantly affect main channels of monetary policy transmission under plausible CBDC designs[10], although operations may need adaptation because of economic agents' balance sheet changes.

4.1 CBDCs and monetary transmission

The emission of CBDC will change the balance sheets of economic agents that can be illustrated with the help of T-accounts (see figure 1)[11]. An important assumption is often made concerning the fact that no change takes place on the liability side of households' and firms' (and government's) balance sheet. However, the volume of agents' liabilities (like credits and loans) and sources of finance (bank credit or bonds/equity) depends both on the demand and on the supply provided by the bank and/or other financial institutions. As we will see further the supply of credit can change with the CBDC emission.

Depending on the degree of substitution between cash, deposits, other assets, and the CBDCs, a central bank may need a larger balance sheet to conduct monetary policy. The volatility of traditional monetary base components may increase, making them less predictable. It will be necessary for the central bank to consider the demand for CBDC to influence interest rates. The interest rate on CBDC can become a "floor" interest rate in the money market; at the same time, CBDCs can be used as additional tools to provide liquidity to the market.

(Mancini-Griffoli, 2018) analyze the possible impact of CBDC emission on four existing transmission channels (interest rate channel, bank lending channel, credit channel, exchange rate channel) and find out that most probably all of them could strengthen because CBDC can become a new instrument affecting interest rates. Thus, a central bank can influence market interest rate more rapidly and efficiently. Moreover, according to (Mohammad and Davoodalhosseini, 2018), CBDCs provide more flexibility for a central bank to conduct monetary policy: a central bank can monitor agents' portfolios of CBDC and can cross-subsidize between different types of agents, but these actions are not possible if agents use cash because of its anonymity during making transactions.

[10] The design includes different features of CBDC. 24/7 availability, anonymity vis-à-vis central bank, peer-to-peer transfer, interest-bearing will make CBDC a more preferable payment instrument (other things equal), and limits will decrease the demand for CBDCs. The greater the agents' demand for CBDC, the more central bank is expected to affect the economy. The demand for CBDCs also depends on how they can be used – as a means of payments and/or a store of value.

[11] See (Gürtler, et al., 2017), (Meaning et al., 2018).

Central bank

Assets ↑	Liabilities ↑
CB credit ↑	Cash ↓
	Reserves ↓
Securities ↑	
	CBDC ↑

Commercial bank

Assets ↓	Liabilities ↓
Reserves ↓	Deposits ↓
CBDC ↑	CB credit ↑

Households

Assets	Liabilities
Deposits ↓	*No changes (?)*
Cash ↓	
CBDC ↑	

Firms (and government)

Assets	Liabilities
Deposits ↓	*No changes (?)*
Cash ↓	
Securities ↓	
CBDC ↑	

Figure 1 – T-accounts in a world with CBDCs

Source: Compiled by the authors, (here red values and arrows show the changes compared to the usual situation).

According to (Mancini-Griffoli, 2018), one scenario, however, would significantly test the standard transmission channels but could be resolved with a change in the operating framework. If banks are no longer involved in intermediating payments, demand for reserves (which are a part of the monetary base as well as cash) will disappear. This scenario resembles the "cashless world" considered by (Woodford, 2000) when demand for one component of the monetary base disappears. Woodford argues that "perfect control over overnight rates would still be possible, through adjustments of the rate paid on central bank balances." No one with access to CBDC would lend at a rate below that offered by CBDC, which would remain the safest and most liquid asset available. This is akin to controlling monetary policy by paying interest on reserves ("floor system").

The general recommendation that can be given to central banks is to issue initially a relatively small amount of CBDC to circulate in parallel with cash and reserves to check the response of monetary policy transmission channels to these changes.

Furthermore, CBDC emission may help to solve the Zero Lower Bound (ZLB) and the Expansionary Lower Bound (ELB) problem in case of introduction of negative interest rates on CBDCs alike negative key rates (see Goodfriend (2016) and Dyson and Hodgson (2016)). Negative interest rates stimulate economic agents to use cash. So, low or zero demand for cash is required to achieve negative rates. That is why the reduction of the number of high-denomination banknotes in circulation is an important condition for the successful overcoming of ZLB (ELB). (see Rogoff (2016), Bordo and Levin (2017) and Pfister (2017)). Still, it is not entirely clear how the economy will function in a situation of negative rates (McAndrews (2017)).

The financial system can incur several risks following CBDCs' emission. The first one is associated with the strengthening of the CBDC role and CB itself in the financial market. The growth in demand for CBCDs without a corresponding decline in demand for the traditional monetary base can lead to:

- the growth of the CB balance and, therefore, to the increase in the demand for market securities by the central bank, which may affect their prices;
- a decrease in the volume of operations in the interbank lending market and its role in determining interest rates.

To sum up, CBDCs have a good potential to become a new effective instrument for monetary authorities to influence the real economy through interest rates and banking channels of monetary transmission. Still, their emission is associated which risks and destructive implications for financial intermediaries.

4.2 CBDC emission problems

There are many "technical" CDBC emission problems. The first one lies in the sphere of legal restrictions related to the right of the Central Bank to issue digital money and the question of the legitimacy of the CBDC as a means of payment (legal tender). So, an important issue is whether central banks have the legal authority to issue CBDCs. Given that most central bank mandates were created way before electronic money or cryptocurrencies, this is not surprising. From a formal point of view, central banks cannot issue their digital currency until changes to the relevant legislation in each particular country are made. According to the BIS survey (Barontini and Holden, 2019), almost 25% of central banks have, or will soon have,

authority to issue a CBDC while a third do not, and about 40% remain unsure[12]. Amendments that are needed to be made to the current legislature require the joint work of both the legislative bodies and the monetary authorities. Moreover, it is important to list agents' types (individuals, firms, banks, financial institutions, foreign sector) that may access CBDCs; and to cover the issues connected with (im)possibility of interest payment on CBDCs and taxation issues. Differences in legal regulations regarding CBDCs in different countries can lead to inflow/outflow of "resources", especially in times of financial distress. So, the monetary authorities of different countries should coordinate their work in the field of CBDCs legal regulation.

An open question is whether CBDC usage and storage is safe and secure in terms of the reliability of "technology" being utilized for these purposes. According to (Mai, 2018), CBDC will certainly have to meet – if not improve upon – the safety level attributed to existing regulated payment methods. With the central bank as an issuer, there will be no legal uncertainties impairing the attractiveness of CBDC. However, people also need to be convinced of the safeness against fraud and operational failure. So far, the technical security of distributed ledger technology has not been tested on a large scale. At the same time, on the one hand, it will be harder to corrupt the ledger, because so many copies of it would have to be manipulated at the same time. On the other hand, the consensus protocol could be manipulated by a malicious (group of) participant(s) controlling the majority of voting or computational power ("consensus hijack"). Besides, cryptographic methods that are safe today may be hacked in the future if computing power increases enough. Huttner (2018) discusses the threats to blockchain technology and digital currencies that can emerge from quantum computing. With the emergence of quantum computing within the next 10 to 15 years, existing cryptography routines may be compromised. Quantum computing can generate a large number of outcomes in a relatively short time, and as a result quantum computers can bypass the existing security mechanisms which underpin blockchain and digital currencies.

That is why one way to mitigate security fears is to issue a relatively small amount of CBDC to circulate in parallel with the existing fiat currency to test the security and other features of the CBDC. Monetary authorities should also test not only DLT but other technical

[12] 63 central banks replied to the survey, of which 41 are located in emerging market economies (EMEs) and 22 in advanced economies. Together, the respondents represent 80% of the world's population and over 90% of its economic output. The survey was conducted in late 2018. It starts by asking central banks if they work on CBDCs development or not and if they do, it further inquiries about the type of CBDC and how advanced the work is. Motivations and current expectations for potentially issuing a CBDC are also queried, as well as whether central banks have the legal authority to issue. Given the complexities involved, central banks also provided a wealth of supplementary qualitative explanations to their answers. See (Barontini and Holden, 2019).

solutions to operate retail and wholesale CBDC payment systems. Central banks should design their systems in such a way that they are not tied to one cryptographic method. According to (BIS, 2018), any CBDC need not necessarily be implemented using some form of DLT; theoretically more traditional centralized technologies may suffice.

The third problem concerns the fact that anonymity carries the risk of potential money laundering or terrorism financing, and so far, no regulator has answered this question. It`s necessary to limit the amount of money on anonymous accounts. According to IMF research by (Mancini-Griffoli, 2018), CBDCs can be designed to facilitate identity authentication and tracking of payments and transfers. But unless required by law, users' information could be protected from disclosure to third parties and governments, while criminals could be deterred by the risk of investigation and prosecution. Although promising on paper, these solutions would have to be further evaluated, and questions answered. Banks would have to comply with the know-your-customer (KYC) principle and anti-money laundering (AML)/combatting the financing of terrorists (CFT) requirements for their CBDC operations.

If central banks start to interact with consumers and nonfinancial firms directly, then part of the functions (like communication with clients and dealing with their requests, ensuring anonymity and confidentiality of information, providing information to tax and other authorities) of commercial banks will automatically go to the central bank. The need to create additional infrastructure by the central bank will be associated with additional costs and risks.

As a conclusion, now, even if the perspectives are fundamentally interesting and promising, the question of CBDC remains highly prospective. However, the examination of the central banks' projects shows that, sooner or later, these instruments for wholesale and retail operations, will be introduced. The main reason, beyond the tendency of the public to use less cash or alternative way of borrowing money, is the necessity to make the monetary policy efficient. Indeed, although the European Central Bank is charging negative interest rates (around -0.4%) on reserves, the commercial banks go on serving positive rates to their customers, to maintain a stable deposit base. In the long term, this will have detrimental effects because, this leads to more risk-taking and banks tend to lend less (Heider, Saidi, and Schepens (2018)). The extension of CBDCs bearing interest to all categories of agents helps to enforce a more accommodating central bank policy. This, even if CBDCs coexist with banknotes when the central banks impose scalable deposit and withdrawal fees, as Agarwal and Kimball (2015) or Rogoff (2015) suggest it. Consequently, the central bank could improve greatly the transmission channel of their overnight rate of interest.

5. Conclusion

As a reaction to the potential threat of cryptocurrencies development, central banks favored the emergence of CBDCs projects. However, the potential creation and emission of such instruments face several economic, technical and legal difficulties, especially for retail operations. Consequently, monetary authorities and international organizations feel cautious about CBDCs' enforcement.

The implications of CBDC emission will largely depend on their design, i.e. on their attractiveness compared to traditional financial assets and cryptocurrencies. These design features include, in particular, ownership rights, place of storage and the use of different restrictions (on type of economic agents and volume of investments), (non) anonymity of payments, the presence or absence of interest income paid on the CBDCs and technology used to make payments.

The emission of CBDCs and their direct use by consumers and firms are likely to lead to the significant changes in commercial banks' role in the payment and financial systems. CBDCs emission may result in a decrease in demand for commercial bank deposits, credit supplied by commercial banks, a potential decrease of the traditional banking system role in the economy and the whole structure of financial markets. At the same time, the emergence of CBDCs should not lead to significant changes in monetary transmission. Moreover, if central banks will pay interest on CBDCs, monetary authorities will receive an additional monetary policy instrument, and the interest channel is also likely to strengthen.

To conclude, currently there are still more questions than ready answers if we speak about CBDCs. The interconnections between risks and benefits of CBDCs emission in the case of each project and country are not obvious and require deeper discussion and further research and analysis.

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Appendix 1

CBDC for wholesale operations:

Pilot Central Bank projects in the area of DLT technologies

Besides the mentioned projects for retail or wholesale operations, we must mention other initiatives that correspond to pilot projects that offer innovative insights. We cannot quote them all, and we invite to report to the very recent publication of the World Economic Forum on March 2019 entitled "Central Banks and Distributed Ledger Technology: How are Central Banks Exploring Blockchain Today?", Ashley Lannquist (2019). This study mentions the most advanced projects in the area of DLT uses. For instance, it is necessary to refer to the following outstanding projects among several others:

a) The Bank of Canada, The Bank of England ant the Monetary Authority of Singapore are defining common projects known as "Project Jasper" and the MAS's Project Ubin" pilots that investigate how CBDC can be applied to improve efficiency, performance, and resilience in domestic interbank payments. The results are mainly synthesized in their common (2018) report titled, "Cross-border interbank payments and settlements" (Bank of Canada, Bank of England ant the Monetary Authority of Singapore (2018), where they define the whole set of problems to solve by defining several scenarios. Space is lacking here to expose fully all this crucial question of harmonizing border cross payment may be solved.

b) The European Central Bank (ECB) and the Bank of Japan are conducting a joint pilot project, "Project Stella". In phase 2, its object is exploring how the settlement of two linked obligations (as the delivery of securities against the payment of cash) could be designed and operated in an environment based on DLT. This mechanism is based on a delivery versus payment. It links the transfer of two assets to ensure that the transfer of one asset occurs if and only if the transfer of the other asset also occurs.

c) The Bank of France:

   In 2016 the Bank of France conceived the project MADRE that now fully replaced its centralized process for the provisioning and sharing of SEPA Credit Identifiers (SCIs). The European Union created SEPA or "Single Euro Payments Area" which

is a payment scheme that aims at achieving an integrated market for payments in the euro area.

MADRE object was to decentralize the SEPA creditor credential register and the assignment of these identifiers. The creditor identifier register becomes a blockchain whose management is shared by all the banks. A SEPA Creditor Identifier (ICS) categorizes each issuer. In France, 60% of applications are filed with three banks. The Banque de France alone collected and managed ICS requests, that the commercial banks sent on behalf of their clients and also, it verified the issuers' document. The process was centralized, tedious and expensive. Then, the Banque de France has chosen to decentralize:

a) The register. This makes it possible to spread the cost of maintenance and brings transparency to the database for commercial banks,

b) The process of assigning identifiers. The allocation and integration of the new ICS in the register is reported at the bank level and automated by the blockchain, relying on smart contracts with predefined terms and conditions. This new system reduces processing time from days to minutes. Thanks to it, the commercial banks can consult all the real-time referencing, and obtain an almost immediate response to their requests for attribution of identifiers. This is done using a decentralized, blockchain-based solution. The project began as a pilot using a proof-of-stake? concept based on an Ethereum blockchain. MADRE automates and digitizes a manual and time-intensive process that requires coordination and information sharing with multiple banks. The Banque de France project is fully working.

d) Other projects: The World Economic Forum mentions still about 10 other projects and pilots that use DLT technologies (Lithuania, Thailand, Brazil, Germany, Hong-Kong, etc.).

As a conclusion, applying DLT for clearing and settlement operations may contribute to diminishing the cost of inter-bank exchanges and increase their safety. It seems a promising instrument. However, several technical, legal and economic question remains to be solved before their implementation. If the MADRE project is now implemented, we must underline that it does not concern payments as such but the identification process of banks' clients. Advanced projects as STELLA are still under a pilot form. However, in the near future, some of them will succeed.

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