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**Central Bank Digital Currency – Challenges and
Opportunities**

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Abstract

The history of central banking started with payment services. Ever since, the payment-related innovation has always been an essential segment of central banking. As electronic devices and high-speed networks are becoming inevitable, central banks all around the world are now actively exploring the possibility of launching their sovereign digital currencies. This dissertation provides a theoretical analysis of the main implications of the central bank digital currency (CBDC). Such investigation is carried out through a literature review that considers some of the most relevant contributions addressing these issues. The analysis reflects initial thinking and experience in this rapidly evolving area, and it may serve as a starting point for further discussion and research.

Keywords: *Central bank digital currency (CBDC); Blockchain technology; Monetary policy; Financial stability*

Introduction

Interest in central bank digital currency (CBDC) has drastically risen over the last couple of years, potentially turning upside down the existing world economic hierarchy. Central banks have embarked on many exploratory projects to study the potential for issuing CBDC. What is clear from these different proposals is that whatever the solution is chosen, it has to be fast, energy efficient and unbreakable, all at once. Privacy and identity must be managed in a way that is acceptable to governments, citizens and corporations. There is no question that the introduction of CBDC will bring many changes to economic world. How powerful and impactful the CBDC will be, depends on number of factors. One of the best determinants of progress is the extent to which society will embrace this new technological innovation. If this extent is big, then it can be said that CBDC has succeeded in its goal.

This dissertation will answer many questions regarding the concept of CBDC. In the first section some of the basic principles will be discussed, such as: definition of CBDC; potential reasons for its issuance, both cash-related and payment-related; different models of CBDC and its architecture. Furthermore, the technology that stands behind the idea of CBDC will be thoroughly explained in the section two. It is the blockchain technology that is ruling the world at the moment, and it is no surprise that this was a choice of many central banks that started the process of implementation of CBDC. Types of blockchain as well as its potential benefits are also mentioned. Section three of the dissertation explores the legal framework behind the CBDC and its related concepts, legal tender, central bank governance, etc. Sections four and five will deal with some of the main consequences, both monetary policy and financial stability ones, of the launching of CBDC. Finally, section six will address some of the applications of CBDC in the real world. Examples of China, Sweden and Lithuania will be introduced as well as their different models of CBDC and digital collector coin.

1. Concepts of Central Bank Digital Currency (CBDC)

1.1 What is CBDC?

As stated by the Bank for International Settlements (BIS, 2018), the term CBDC is used to refer to a number of different concepts. Because of the mix of already existing central bank currencies and new ones, it is not easy to define what CBDC precisely is. However, the majority would agree that this is a new form of central bank money – a central bank digital liability, denominated in an existing unit of account, which will serve as both a medium of exchange and a store of value. Another definition, given by The Bank of England, says that CBDC is an electronic CB money that: can be accessed more widely than reserves; should be much more functional than cash for retail transactions; has an autonomous operational structure to the other forms of Central Bank money and finally it can be interest bearing. According to internal Banque de France, CBDC is a digital money that can only be issued or destroyed by the central bank itself, that is available 24/7 and that circulates on a digital media that are at least partially different from the already existing media.

There are two ways in which a central bank may issue a digital currency – as a wholesale CBDC and as a retail CBDC. Wholesale currency is a digital token that can only be used for interbank payments and held by financial institutions. On the other hand, more important to us, a retail CBDC is a new digital means of payment meant for the general public. Its main goal is to provide a solution to digitizing physical cash.

An important thing to point out is that CBDC is not a cryptocurrency. Although it often gets thrown into the bucket of cryptocurrency it is in fact very different because it keeps banks at the heart of every transaction, unlike the other one. E.g. it could manifest itself as account-based or a token; in the latter case, each token would go directly to the central bank. CBDCs are traditional money, but in digital form, issued and governed by central banks around the world. On the other hand, cryptocurrencies, such as the most famous Bitcoin, are produced by solving complex math puzzles and governed by online communities instead of centralized state bodies. Bitcoin and other virtual currencies are restrained with wild volatility, while CBDC seems to offer much more stable price. The main characteristic the two of them have in common is their technology base. As per now, it is a

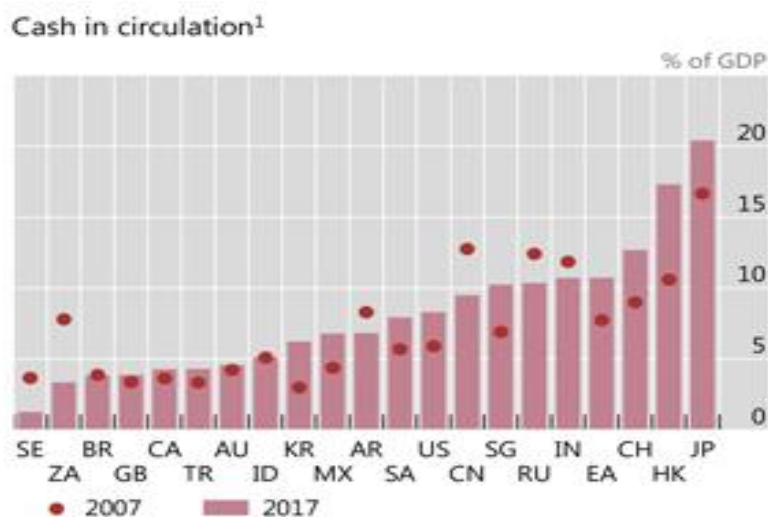
blockchain technology, a digital ledger that allows transactions to be recorded and accessed in real time by multiple parties.

1.2 Reasons for issuing CBDC

1.2.1 Cash-related aspects

In many countries around the world, the demand for paper currency has been quickly diminishing, as consumers started turning to using credit/debit cards as well as their cellphones and online payment systems. For instance, Swedish households used cash for approximately only 15% of their transactions in the last year, in comparison to 30% only couple of years earlier. One of the major economic issues for all the cash cycle stakeholders is the cost of cash management. In one of the recent papers, France's Banking Federation estimated that the net cost to the banking sector of cash management was approximately 2 billion euros per year. With decline of banknote and coin processing, the costs of cash management should be considerably lower, as the process of developing and managing the circulation of a CBDC would take much less effort. From the consumer's perspective, a retail CBDC should make it possible to lower the costs related to the time spent getting to a cash delivery point, withdrawing cash and making the final payment. In a cashless society, it is forecasted that there would be neither coins nor paper notes available to individuals and that all the money would be exchanged in a digital format.

Graph 1: Cash in circulation as a % of GDP



Source: Bank for International Settlements (2018)

However, the trend of diminishing demand for paper currency is not uniform across countries or types of households (e.g. as seen in the graph 1, the amount of cash in circulation is about 10% of GDP in the Euro Area, 12% in Switzerland and it exceeds 20% of GDP in Japan - which is not a negligible statistic). Even in Sweden, that has the lowest percentage of cash in circulation as part of GDP, a recent Riksbank survey indicated that more than one-third of households would not be able to cope with the disappearance of cash. They also pointed out to the problem of the elderly people and individuals with relatively low level of education, who would also struggle in a cashless society. It is not envisaged that there will be a move to ban notes and coins, and the considerations mentioned above weigh strongly against the sudden abolishment of cash. What central banks could do in this case, is facilitate the gradual obsolescence of cash by making their CBDC widely available to the public and by initiating a graduated schedule of fees for transfers between cash and CBDC. Such arrangements would also foster individual freedom of choice and at the same time would discourage tax evasion, money laundering and other illegal activities that are made easier by paper currency, especially with large-denomination bills. This benefit is important in advanced economies, but especially important for developing countries where the large fractions of economic activity are conducted by cash and where the presence of tax evasion is still very high. Another potential benefit of a retail CBDC is that it would offer less anonymity than cash, since the cash can be used without having an intermediary, while an account based CBDC would circulate between accounts. This would discourage illicit activities in the shadow economy. However, if they want, individuals will still be able to preserve their anonymity by engaging in small retail transactions by using cash, or alternatively, virtual currencies or other private payments.

1.2.2. Payment aspects

Among the main potential benefits in the payment systems area, efficiency should be pointed as the first one. CBDC can reduce friction in existing payment systems, both retail and large-value ones, as well as provide them safety. Having a CBDC could decrease monetary costs, it could facilitate faster settlement and extended settlement hours. One of the interesting ideas is the removal of low value coins through delivery of electronic change. Similar proposal was actually made by the Bank of Korea in April 2017, when they started a “coinless society trial”, allowing the customers to deposit their small change onto prepaid cards instead of accepting them. The idea came from the fact that in 2016 only the country

of Korea spent 53.7 billion Won (approx. 38.2 million euros) on producing coins. It turned out to be a great cost saving benefit. Another function that CBDC may perform is acting as a payment backstop to private sector managed payment systems, in order to avoid breakdowns of payment systems in times of crisis.

1.3 Models of CBDC – token or account based?

Money is typically based on one of the two technologies – either tokens or accounts. For example, cash is token-based. Many digital currencies are also token-based, in the sense that they are linked to a physical medium, such as mobile phone, payment card or hard drive. On the other hand, account-based forms can be commercial bank money, balances in reserve, etc. Digital currencies can also take this form, and if they do, they are stored in an account linked to the holder and accessible online. A retail CBDC should circulate in one of these two forms. A key distinction between them is the form of verification that is needed when the exchange happens (Kahn and Roberds, 2009). Token-based payment systems depend largely on the ability of the payee to prove the validity of the payment object. With cash - the worry is if it is forged, with digital money - the worry is whether the token is genuine or not (electronic forgery) and whether it has been already used. On the contrary, with account-based payment system, the fundamental thing to do is to make sure to verify the identity of the account holder. Identification is needed in order to correctly link payers with payees and to ascertain their account histories. If CBDC tokens were issued, they would circulate electronically among the private individuals and firms, similar to bitcoin, but with the difference that the central bank would determine the supply of these tokens, which would be fixed in nominal terms and would serve as a legal tender. Under the alternative method, account-based method, firms and individuals would hold their funds electronically in CBDC accounts at the central bank or in specifically created accounts at depository institutions. In this case, the central bank would process each payment transaction by simply debiting the payer's CBDC account and crediting the payee's CBDC account (Bordo and Levin (2017)).

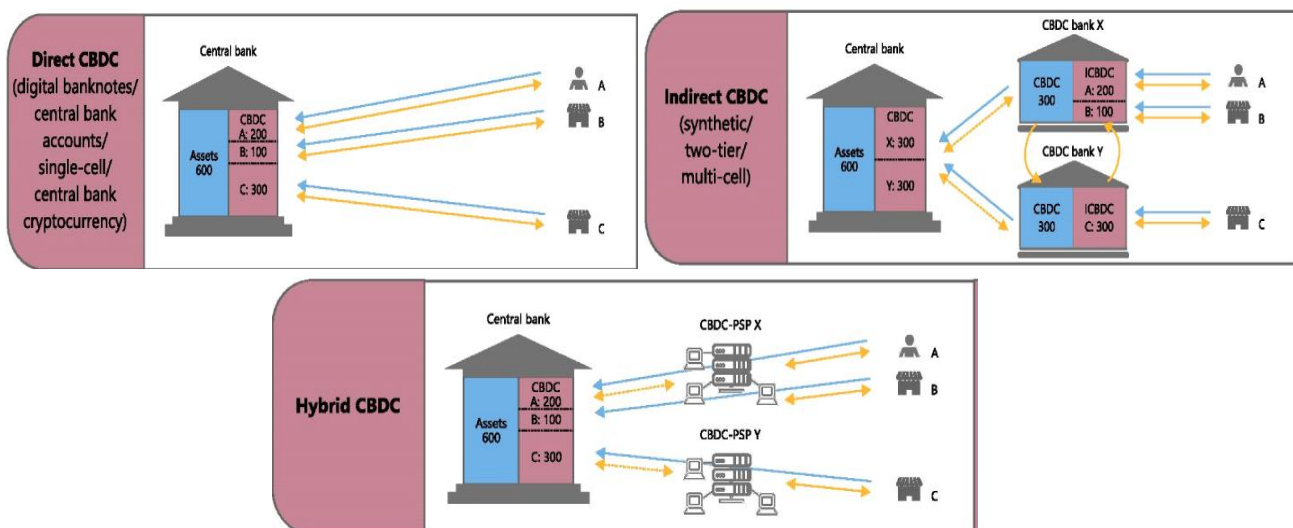
One of the main benefits and advantages of the account-based method is that the payments would be almost instantaneous and costless. There is an initial creation of each account that would require the verification of the identity of the account holder, which can take some time, but once it is finished the transactions could be managed rapidly and securely. On the other hand, the cost of verification in the token-based system would be much more

expensive. The entire chain of ownership of every token must be stored in a blockchain, and this process itself would involve computational procedures that are really complex and energy intensive. One of the cons of the account-based method is that it is the online model only, because for initiating an asset transfer it is required to have an access to the online account. Token-based model may potentially work in offline mode, with the possibility of transferring tokens between media without being connected to the internet.

1.4 CBDC architecture

In all three architectures shown in the figure 1 below, by definition, the central bank is the only one that has the power to issue and redeem the CBDC. Also, all three of them could be either token-based or account-based.

Figure 1: An overview of potential CBDC architectures



Source: Bank for International Settlements (2018)

Firstly, there is a direct model, with no intermediaries involved, with CBs that themselves provide the digital currency to the end users and with CBs that are the only ones handling the payment systems. A CBDC directly operated by the central bank is attractive because of its simplicity, as it does not include any other intermediate bodies. However, if central banks were to take on this responsibility, it would require a massive expansion of their operations which they may find difficult to achieve. Secondly, there can be an indirect or synthetic model – where CBs use intermediaries to provide the digital currency to the end users. These intermediaries are mandated to fully back each CBDC liability to the consumer via its holdings of the actual CBDC. The downside of this method is that CBs do not keep record of individual claims, only the intermediate bodies do. Finally, hybrid model combines

the previously mentioned two, which provides CBs with direct claims while allowing the intermediaries to handle the payments. This model has both advantages and disadvantages in comparison with direct and indirect one. It should be stated that it is much more simpler to operate than the direct one, since CB can concentrate on a limited number of core payments, while the intermediaries can take care of other services that require instant reactions. Also, in comparison with the indirect model, it might offer better resilience but with the cost of a more complex infrastructure for the central bank.

1.5 Interest-bearing CBDC

As mentioned in one of the definitions of CBDC in the section 1.1 of the dissertation, CBDC can be interest bearing. What does it mean? From a technical perspective, all funds, whether they are held in the bank by an individual, firm or financial institution would bear the same nominal interest. This approach is similar to current arrangements of many central banks around the world, which pay interest on the reserves of commercial banks that are held electronically at the central bank. Paying the interest on CBDC can contribute to developing of competitiveness of the banking system. In a growing economy that has stable prices, nominal interest rate paid on CBDC would typically be positive. On the other hand, cash accrues zero interest, and therefore it becomes increasingly attractive as a store of value when the nominal values are negative. If these values were pushed too far below zero, the financial system could undergo a severe disintermediation into cash. In order to eliminate this constraint, central banks may impose graduated schedule of fees on transfers between cash and CBDC – which would make it unprofitable for investors to disintermediate into cash when nominal interest rates are negative. In this way, the interest rate on CBDC could serve as the primary tool of monetary policy, and monetary policy would no longer be constrained by an effective lower bound on nominal interest rates.

2. Technology

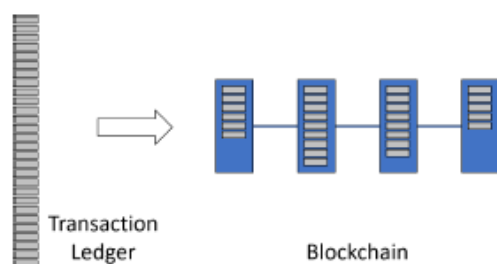
As stated by BIS (2018), many central bank-operated payment systems are at the end of their technological life cycles, with outmoded and inefficient architectures. This is one of the main reasons for new technologies to arise and replace these out-of-date payment methods. CBDC could be built by using either blockchain technology, which will be explained later on, or some other conventional and centralized technologies. In this case, without employing blockchain technology, the digital currency units would not be equivalent to coins or tokens, but rather to a form of electronic currency.

In one of the recent BIS's studies, they found out that more than 80% of the central banks are looking at a blockchain-type technology as a place to issue their digital currencies - therefore, in the rest of section 2 the main focus will be on this type of technology. The blockchain would serve as an alternative to standard types of infrastructure already used in central banks (Real-time Gross Settlement System – RTGS and securities settlement system).

2.1 What is blockchain?

Before defining blockchain, it is important to know what Distributed Ledger Technology (DLT) is. A distributed ledger is a consensus of replicated, shared and synchronized digital data geographically spread across multiple sites, countries or institutions (Ward & Rochemont, 2019). The DLT database is spread across several nodes on a peer-to-peer network, where each node replicates and saves an identical copy of the ledger and it updates itself automatically and independently. Each transaction, such as simple transfer of funds or an interaction with smart contracts, is serialized in a single ledger. When many transactions are aggregated together into so-called blocks, each containing many of them, the blocks are linked to form a chain and therefore it got the name – *blockchain*.

Figure 2: Each block contains transactions and the block order determines the global transaction order



Source: Allen et al (2020)

A blockchain is a type of DLT where transactions are recorded with an unchangeable cryptographic signature called a hash. Blockchain enables multiple users to make entries into a record of information, and it also allows them to control how the record of information is updated and altered. Each node, by updating itself independently, eliminates the need for a trusted party to intermediate the digital relationships. In order to participate in the blockchain, each participant must have a digital identity.

There is a skepticism from some central banks about the current potential of blockchain technology for economic applications. The following table summarizes positions of world central banks towards the blockchain.

Table 1: Central bank attitudes towards blockchain

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

Source – Ward and Rochemont (2019)

2.1.1 Types of blockchain

Based on the access to blockchain data, we can classify blockchains into 4 categories: private, public, permissioned and permissionless. In the private one, a single centralized body or a limited predefined list of entities have complete control over what is written in the ledger and there is only one writer. A public blockchain is the type where there are no restrictions on reading the data and no restrictions on submission of transactions for inclusion into the blockchain. A blockchain where the writing privilege is granted to a consortium of entities with known identities is so-called permissioned blockchain. This consortium controls the policies and they are the only ones to verify the transactions. Finally, a permissionless blockchain is similar to the previous one with the main difference that there is no restriction on the identities of the transaction processors (users that are eligible to create blocks of transactions). Usually, the terms private and permissioned are used

interchangeably, as well as the terms public and permissionless. The table down below nicely summarizes these different types of blockchain as well as their main characteristics.

Table 2: Types of blockchain

	PUBLIC BLOCKCHAIN	PRIVATE BLOCKCHAIN
• <i>Access level</i>	No limitations	Single, centralized body
• <i>Participation</i>	*Permissionless Anonymous	*Permissioned Identities are verified
• <i>Security</i>	Consensus Mechanism Proof of work	Pre-approved entities Voting
• <i>Performance level</i>	Slow transaction speed	Faster transaction speed

Source: Author

2.1.2 Potential benefits

Blockchain technology brings unique advantages to a CBDC. First of all – system trust. A digital currency based on a blockchain system enables CBs to control it and at the same time provide the privacy and independence of its usage to the end users. This is one of the crucial facts, because without system trust CBDC cannot attract new consumers. Secondly, data availability. DLTs such as blockchain ensure data availability and resilience, in addition to trust and transparency related to transaction history. In addition, blockchain-based CBDC would benefit from the innovative products and services that are being constantly built across the blockchain ecosystem.

In the blockchain community, one approach that has received a significant amount of attention recently is the notion of the self-sovereign identity. Briefly, the main idea is to build an identity ecosystem through blockchain which would allow users to collect digital authentications from participating individuals. Users might collect in their digital wallet data like name, address, birthdate and other personal data, degrees and certificates earned, etc. The concept of self-sovereign identity is promising in that it will give users the control over how much and which attributes they're comfortable revealing to a particular counterparty and it may overall help facilitate transactions with CBDC.

Blockchain plays really important role in the research and development of not only CBDC, but also cryptocurrencies. This may be helpful for the establishment of secure payment and trust system of CBDC. Blockchain may affect number of different things related to development of payment industry and CBDC itself. To start with, costs – blockchain based payment systems may offer lower transaction cost, especially in the cross-border payments, currency exchange and other payment scenarios. In the second place, usability – in comparison with other traditional payment methods, blockchain makes the transaction process more intuitive and easier to integrate with other services.

Blockchain is a fresh technology that has an extensive application potential, which can not only be used as a base for the payment systems, but it can also be adopted by financial market infrastructure (FMI). It may cause a positive impact on the overall financial system and other networks in the whole economy. It should reduce the cost of trading; give small firms access to the global market; improve transparency and security of all transactions; improve monitoring and management of the markets; strengthen intellectual and property rights; improve governance and social outcomes in the developing countries, etc.

2.1.3. Specific aspects related to blockchain use

The main idea behind the concept of a wholesale CBDC, as already mentioned previously, is to enable central bank money to circulate between financial or non-financial institutions in order to settle the transactions. A retail CBDC on the other hand is meant for general public. Both of them are most likely to be associated with a blockchain technology that offers an alternative to current RTGS or other payment and security settlement systems. This raises a several questions, both technical and functional ones. Does it mean that for a wholesale CBDC the only compatible blockchain would be the private one? Most likely yes, because the choice and number of blockchain participants would solely be determined by the central banks and by definition it would be issued to a limited number of financial sector users. This approach will make it possible to reduce the operational constraints associated with approving transactions simply by accelerating this process, as we know that in the private blockchain all identities are verified or pre-approved. Could there be a potential circulation of the wholesale CBDC on several blockchains, if they are private? This circulation would be complex for central bank to oversight and it could have implications for financial stability and monetary policy transmission that are difficult to anticipate (Pfister et al, 2020).

2.2 Real-Time Gross Settlement (RTGS) system

As already mentioned, although widely represented, blockchain is not the only technology that could be used for building up CBDC. Probably, the other most famous one is RTGS, whose main features will be briefly explained in what follows.

RTGS refers to a payment transfer system that allows for the transfer (instantaneous) of money and securities from one bank to another. It is a continuous process of settling payments on an individual order basis without netting debits with credits across the books of central bank. In addition, RTGS can contribute to the reduction of settlement risk in securities and foreign exchange transactions by providing a basis for delivery-versus-payment (DVP) or payment-versus-payment (PVP) mechanisms (Lucas et al, 1997). Traditionally, RTGS is at the center of the system of central banks around the world and it is typically used for high value transactions that require and receive an immediate clearing.

Current RTGS infrastructure provided by central banks is highly secure and reliable. One might wonder then why more than 80% of CBs chose blockchain as a primary solution for CBDC. One of the reasons is that RTGS is expensive from the point of view of collateral consumption. A blockchain alternative, based on DLT, has the potential to reduce the collateral needs. The role of central bank as guarantor of the transactions would be decentralized, with potential efficiency gains. Blockchain would probably open the door to more participants beyond banks, which would increase competition and reduce costs.

3. Legal framework

The legal framework of CBDC must include the body of law which will determine rights and responsibilities of the parties in the system. It also involves laws that are generally applicable to the payment system and instrument that are specific to it.

Central banks face many legal, regulatory and governance challenges in connection to issuing of CBDC. In order to fix these issues, some of them may need to amend their legal frameworks related not only to digital currency, but also to legal tender, central bank governance and internal organization. As stated by Lönnberg (2013): “Strengthening the institutional capacity of the central bank and ensuring it has the resources needed are critical preconditions for currency reform.” Central banks will have to analyze to what extent and under what circumstances their legal framework allows for CBDC issuance.

When discussing legal framework, one thing that must be taken into account is the role of European Union. How will the CBDC function inside EU? In multilayered constitutional arrangements, such as that of the EU, the principles of subsidiarity and proportionality impose additional limitations on the power of the EU agencies, institutions and bodies. One of the interesting questions is whether the European Central Bank (ECB) will have the power to issue a CBDC and should that currency be a legal tender? In the sub-sections to come, there will be more word on this.

3.1. The question of legal tender, CB governance and internal organization

The definition of legal tender, which is usually applied to banknotes and coins issued by central banks, varies across different jurisdictions. In general, legal tender is anything recognized by law as an instrument to settle a debt or meet a financial obligation, such as tax payments, contracts, and legal fines. On the other hand, the definition of the currency is strict, and it refers to the unit of account which serves as a medium of exchange denominated by reference to that unit of account, as prescribed by law. Currencies are given the status of legal tender under the state’s legal framework, and by this, the debtor is entitled to discharge his monetary obligations with this currency. Changes in legislation may be needed for CBDC to become a legal tender. The concept of legal tender poses two relevant questions for central banks (Kiff, Alvazir et al, 2020). Firstly, can this definition of legal tender be applied to retail CBDC? If, for example, a retail CBDC is denominated in the existing domestic currency there would be no consequences for this retail CBDC as legal tender, because from the moment of creation it would be a legal tender. If, for example, a

retail CBDC would be denominated in anything other than the currency legally decreed by state, than the central bank would need to ascertain if this would require changes to that designation. Secondly, has the concept of legal tender been subjected to enough supervision? Several central banks, such as the Swedish Riksbank, suggested recently a whole new review of the concept itself and they want to find out what does exactly legal tender imply in a digitalized economy.

Several possibilities and outcomes have been discussed throughout different papers. If CBDC acquires the legal tender status, the consequences would not be neutral from the practical point of view, as the payees would have to have access to technological equipment required to receive a payment in CBDC, which raises a question of equal access. This might result in an obligation of public authorities to provide such materials to the affected groups of the public. Another option may be that CBDC would not have a strict “by word” legal tender status, but there will be an obligation to be accepted as a payment method. However, according to Banque de France, this could create potential technical constraints that would have to be assessed, i.e. the need to be able to quickly provide a potentially large amount of cash.

Besides legal tender, before issuing CBDC, central banks must consider their governance, internal organizations as well as the risk management. New digital currency would require clear understanding of its key issues from all the employees, both Board and operational-level staff. By clear understanding it is possibly implied: objectives of the CBDC; policy consequences, such as the position of CBDC within governmental policies; technical requirements for issuing the new currency; cyber security; potential operational, legal or reputational risks; data collection; transparency and accountability requirements, etc. Accounting sector in central banks would probably need further clarifications on CBDC. In July 2018, the International Accounting Standards Board (IASB) has published a paper on digital currencies. In this paper various possibilities regarding to digital currencies have been discussed. But what it notes is that digital currencies are: not a cash under IASB, not real means of exchange, not issued by central bank, not a financial instrument and possibly an intangible asset. Of course, from current point of view, not all of this can refer to CBDC, as we know that they will be issued by central banks, but it is clear that a lot of parts regarding the accounting part must be resolved. Besides understanding the key characteristics of CBDC and major accounting problems, a list of questions to be addressed is long. Kiff,

Alwazir et al (2020) in their paper “A Survey of research on retail CBDC” have published an excellent table that summarizes some of these questions.

Table 3: CBDC Central Bank Internal Organization Analysis

Question	Examples	Comments
What central bank objectives and/or functions will the CBDC serve?	For instance, payment system stability, price stability, financial stability (macro prudential oversight, micro prudential supervision, ELA/LOLR, resolution), financial integrity, financial inclusion, consumer protection, economic growth. Possible links / interaction with the central bank's strategy plan.	CBDC can serve multiple central bank objectives. However, like existing central bank instruments, the central bank needs to be aware of and balance potential conflicts between objectives and therefore the use of CBDC.
What are the technical requirements for CBDC?	For instance, a gap analysis of existing infrastructural and technological requirements for and limitations to setting-up and issuing CBDC. See previous subsection on technological infrastructure, and cyber-security.	Identified technological limitations should be assessed from a risk perspective and a financial perspective (see next point), to ensure a realistic overview of what CBDC possibilities the central bank could explore.
What are the internal organization requirements?	For instance, building up of expertise and training of staff, risk management (third-party involvement / procurement and outsourcing risk, contractual arrangements, cyber security, and other operational, legal and reputational risks for the central bank), budget requirements and restrictions, data collection and data management requirements.	A complete overview of internal organization requirements (which could also be in part based on internal and external audit findings, and internal and external organization assessments) would help to identify the relevant contextual issues for setting-up and issuing CBDC.
How will transparency and accountability over the CBDC be shaped?	For instance, internal audit findings, accounting mechanisms, and internal and external communication.	Transparency by the central bank on CBDC developments will allow for proper accountability to its stakeholders (parliament / society), which on its turn could lead to strengthening / clarifying the central bank's mandate and legal framework (see previous subsection).

Source: Kiff, Alwazir et al (2020)

3.2 European Central Bank and CBDC

In accordance with general principles, the ECB has a direct mandate and limited regulatory and supervisory tools to accomplish the objectives of that mandate. In addition, the ECB's acts, besides recommendations and opinions, are subject to review and analysis by the European Court of Justice. In accordance, launching CBDC by the ECB should be grounded on the European constitutional, monetary and financial laws. Currently, the ECB is given the exclusive right to print and issue banknotes and coins, which have the legal tender status within the Union, in order to achieve price stability objective and implement the monetary policy. But, already existing European treaties do not provide explicitly the information on

issuance of CBDC. Issuance of the CBDC would have to be integrated in the already existing treaty provisions if amending the legal texts wants to be avoided. If there is a necessity to amend the treaties, then this would have to be done through a new treaty, with accompanying difficulties such as the need for unanimity and ratification processes in the Member States of EU (Pfister et al, 2020) Although under a derogation in the Article 129 of the Treaty on the Functioning of the European Union is stated that the Statute of the ECB and of the ESCB (European System of Central Banks) can be amended using the legislative procedure, this does not bring much help. The derogation is restricted to only a limited number of Statute articles, such as Article 17 on opening accounts, and the derogation authorizes only marginal amendments to the content of the other articles. Therefore, from a public law perspective, the legal basis for issuance of the CBDC by the ECB is not as easy as it seems at the first look.

There is no unique opinion on what should be done regarding the amendments of the Treaty. One may argue that there is no need for the amendment by saying that the exclusive right to issue banknotes and coins would automatically include the issuance of the CBDC, which appears to be their digital representation (Pfister et al, 2020). In addition to issuing banknotes and coins, the ESCB's competence in the area of payments promotes the smooth operation of the existing payment system and ensures safety and efficiency. Also, the ECB's task to provide requisites "to ensure efficient and sound clearing and payment systems within the Union and with other countries", may support the idea that ECB can issue CBDC. Furthermore, the ECB can be a stimulant for change in that by promoting and encouraging technological and legal foundations for financial market infrastructure and it can contribute to the efficiency and stability of payment systems.

An opposite argument may say that despite the potential positive impact ECB may have - CBDC is a programmable digital money whose nature is different from that of the physical paper notes and coins. The ECB will be furnished with new de facto powers, and such effects could give rise to new legal concerns about the scope of competences of the ECB. According to Article 127 of TFEU "the ESCB shall act in accordance with the principle of an open market economy with free competition, favoring an efficient allocation of resources, and in compliance with the principles set out in Article 119" By giving the power of issuing CBDC to ECB there would be a violation of this provision if it leads to a centralized allocation of credit by central banks, which would be a possible scenario in the absence of appropriate safeguards.

It is certainly true that back in the days when treaties were written the authors did not imagine that banknotes and coins might be in any other form than physical. So, what are the options for solving this problem?

One option would be to include the issuance of CBDC under one of the basic tasks of the ESCB set down by the TFEU Art. 127(2). In this way it can be shown that such issuance became necessary in order to maintain the ability to implement monetary policy, which does not seem to be so convincing. Another suggestion, which would have a restrictive impact on the characteristics of CBDC, would be to equate the CBDC to a digital form of banknotes. This leads to the conclusion that the CBDC would have to function in a very similar way to the way that banknotes are used. This option would also make denomination-related constraints, because unlike banknotes, coins are issued by Member States – unless those Member States agree to issue digital coins. As we can see, the question whether ECB should issue CBDC remains very complex.

4. Monetary policy aspects

During the last few decades, monetary economists have come to an agreement that conducting monetary policy should be done in two ways – systematically and transparently. By doing so, the effectiveness of the monetary transmission mechanism is facilitated, as well as the central bank’s accountability to elected officials and to the general public. Launching of the CBDC would provide a huge opportunity for enhancing of transparency of the central bank’s monetary policy framework, including its two parts – nominal anchor and tools & operations.

Regarding the nominal anchor, as stated above, the main goal of central banks is to provide a transparent anchor that enhances private sector’s economic and financial decisions. In theory, the inflation target that is set by central bank would be permanently fixed, it would be credible, and it would have a constant value. But in practice, that is not the case, and the choice of the target has seemed in some parts subjective and arbitrary (Bordo and Levin, 2017). By contrast, with the adoption of the interest-bearing CBDC, that has been discussed in section 1.5 of this paper, central banks could establish a constant price level target that could serve as a focal point for expectations and thus serve as a credible nominal anchor.

Besides its possible positive effect on price level target, the interest-rate on CBDC could also serve as a primary tool of monetary policy. Thus, the central bank’s balance sheet could become very transparent. According to Bordo and Levin, the central bank would generally hold short-term government securities in the same quantity as its liabilities of digital currency. It would simply engage in purchases and sales of this short-term securities so that the supply of CBDC could move together with changes in demand for CBDC.

The consequences of CBDC issuance for the implementation of monetary policy are directly connected to how wide access to CBDC is and whether it is attractively implemented. If CBDC emerges as an attractive asset to hold, it is much more likely that monetary policy implications will be pronounced. Depending on the crucial design features, such as the accessibility by different types of agents, availability beyond intraday use and level of the interest-bearing rate, if all positive, CBDC may have an impact on the channels of transmission of policy rates to money market and beyond. In particular, an attractively remunerated CBDC could affect the institutional investors’ holdings of other liquid, low-risk instruments. If they hold such instruments without limits, the interest rate on it would help establish a good base or “hard floor” under money market rates, which is definitely useful.

In addition to the above-mentioned monetary policy effects, launching of CBDC may strengthen the pass-through of the policy rate to money markets and deposit rates, and it may help to weaken the zero lower bound constraint.

How can the pass-through of the policy rate to money markets be strengthened? If households considered digital currency as an alternative to commercial bank deposits, banks would have less range of power for independently setting the interest rate on retail deposit. For example, banks would really struggle if they do not increase the deposit rates at the same time when central banks were raising the CBDC rate. In this way, a change in the policy rate could be more directly transmitted to bank depositors, and pass-through strengthened.

In general, negative rates on central bank liabilities could provide the monetary stimulant needed in extreme circumstances. Proponents suggested that creation of CBDC could serve to alleviate the zero lower bound if it came along with a diminished desire for cash holdings (Dyson and Hodgson, 2016). Some of their supporters also added that having a substitute for cash in the form of CBDC with interest-bearing rate, makes the discontinuation of higher denomination banknotes easier to achieve (Bordo and Levin, 2017). On the other hand, opponents may argue that weaker demand for cash does not imply the need for a CBDC. In their opinion negative nominal rates carry with themselves number of different legal, operational and economic frictions which limit the potential boost of aggregate demand. They also state that a negative rate carried by CBDC may not address effectively the zero-lower bound, considering political economy consequences, because it is uncertain how deeply negative rates may work in practice (McAndrews, 2017).

The overall effects of CBDC on the structure of interest rates are very difficult to predict and it will depend on many factors.

5. Financial stability impacts

By issuing a retail CBDC, the financial stability could be compromised through transfers of bank deposit fund to the retail CBDC in the times of crisis. Specifically, the retail CBDC could facilitate bank runs (Shirai, 2019). One of the responses to this accusation may be that a retail CBDC would supply central bank with a lot of informational advantage, because it would learn instantaneously that a run was starting. It could then take action much faster than it would usually do as a lender of last resort (LLR) and stop the liquidity problem from turning into a solvency crisis. However, great amount of real-time information on bank liquidity is already available to central banks through their infrastructures for interbank settlements and monetary policy operations. What could happen is that the threat of more recurring runs may actually encourage banks to adopt a more careful approach from the beginning.

To diminish the risk of the bank run, several proposals have been made. One of them is to set maximum amounts for retail CBDC holdings (Mancini, Grifoli et al, 2018). Bordo and Levin (2017), in one of their works suggested to apply fees to converting bank deposits and banknotes to retail CBDC. If nothing is done - the possibility of more frequent runs is accepted, then the question of the procedures used by the central bank to perform their function of LLR is being raised with much greater importance today. It is very important for central banks to establish ex-ante mechanisms that will explain in detail all the procedures for their involvement as LLR. The literature on the lessons of the financial crisis highlights the benefits of this in-advance preparation.

Furthermore, whether the retail CBDC is distributed by the central banks themselves, or it is done through an intermediary, the usage of central bank money eliminates counterparty risk and does not call for provision of coverage by a deposit guarantee mechanism. Two things should be specified regarding this removal of the risk. Firstly, if the CBDC is distributed indirectly, one of the things that may happen is the failure of an intermediary, which could lead to potential operational difficulties. In case this happens, there must be another one that is ready to take over quickly. Otherwise, if a CBDC holder wants to convert its CBDC into bank money in order to make a payment, and his intermediary fails, then there is a chance for liquidity and contagion risk to happen. So, what CB should do is to try to anticipate this type of risk by setting up the mechanisms to ensure that a different intermediary is always ready to take over the responsibilities that were assigned to the failed

one. Secondly and similarly, in the indirect distribution scenario, the risk of fraud connected with the counterparty risk cannot be totally ruled out even in theory. Again, central bank can only try anticipating a situation in which it would be feasible for an intermediary to steal from the customers' CBDC.

A potential risk that is rising from the introduction of a CBDC is greater competition, which in turn lowers the profitability and reduces the financial stability of the commercial banks (Ward & Rochemont, 2019). Commercial banks would have to compete with a lot of new CBDC accounts by offering higher deposit rates, and the reduced revenue from cross border transactions would have an impact on them. This holds under the assumption that central banks conduct cross border transactions more efficiently than the standard commercial banks. Lower profitability may incentivize commercial banks to invest in highly risk assets in a search for revenue. What they would also likely do is increase the dependence on overseas wholesale funding.

The most significant and most likely financial stability risk of a general purpose CBDC is that it can make it easier to fly away from private financial institutions and markets towards the central bank. When facing the systemic financial stress, households and other private agents in both developed and developing market economies tend to suddenly shift their deposits towards financial institutions that are believed to be safer or invest them into government securities. What CBDC would do here is allow for "digital runs" towards the central bank with unprecedented speed and scale, thanks to blockchain technology. The more depositors run from the weaker banks, the more CBDC becomes the favored destination.

6. Who is ready for CBDC?

6.1. China

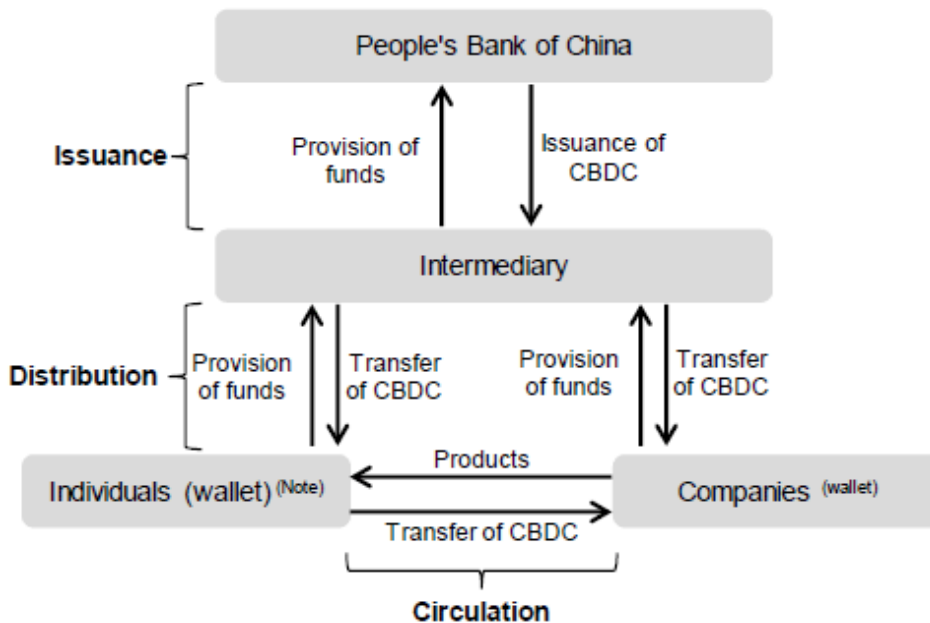
As expected, the fastest growing world economy – China, is leading the world in CBDC development. Their research concerning CBDC began back in 2014 when Zhou Xiaochuan, at that time governor of People's Bank of China (PBoC), mentioned the need for studying the possibility of central bank creating digital currency. Quickly after this, the study team was created inside the PBoC and after 3 years they established Digital Currency Research Institute. Speaking at the 3rd China Finance 40 Forum, Mu Changchun, the head of the above-mentioned Institute, stated that China's CBDC project is moving closer to the introduction stage and explained the details of the planned CBDC scheme. As of August 2020, PBoC has presented the pilot program for the digital currency electronic payment (known as DCEP or digital yuan) in Xiongan, Shenzhen, Suzhou and Chengdu. Although many countries are researching CBDCs, China is a step ahead of them in the international competition. So, how does exactly DCEP work?

Firstly, the DCEP is token based digital currency. The DCEP will serve as a substitute for M0 (cash), but not for M1 (cash + demand deposits) or M2 (cash + quasi currency, i.e. time deposits). This suggests that the DCEP should function as an instrument of settlement, rather than as an instrument of storing value. M1 and M2 have already been digitalized in the form of account management, so there is no need to use other technologies and that is why DCEP will only substitute M0. One of the main reasons stated for promoting the CBDC in China is that banknotes and coins are not only expensive to print and issue, but also, they require continuous investment in research and development of the technologies that will fight against forge. Additionally, they point out that cash is subject to the risk of being used for money laundering or financing the terrorism because it provides full transaction anonymity. By issuing the DCEP China hopes to repress these issues.

Secondly, People's Bank of China decided to base the issuance and distribution of DCEP as well as the whole operation of CBDC scheme, on a two-tiered system. In the first tier we can find transactions between the central bank and its intermediaries, such as banks. Meanwhile, the second tier is comprised of transactions conducted between intermediaries and retail market participants, i.e. individuals and firms. The PBoC will issue the DCEP to its intermediaries. After receiving it, the intermediaries will distribute it so that it can circulate

through the financial market. Most likely the intermediaries will include non-financial companies, such as Alibaba or Union pay, but it will also include four major commercial banks in China – China Construction Bank, the Bank of China, the Agricultural Bank of China and China Construction Bank. There will be no bank accounts, but rather the electronic wallets between which will occur the transfer of DCEP.

Figure 3: Chinese two-tiered system



Source: Hung (2019)

Although many authors have pointed out the benefits of interest-bearing CBDC, the PBoC has decided to issue a digital currency without paying any interest on it. They stated that this decision was made in order to minimize the competition between the DCEP and bank deposits, with the possibility for this to change in the future.

One of the interesting facts is that PBoC managed to take advantage of token-based digital currency, and they provided the option of the settlement in the offline mode. As long as both sides that are performing transaction have a smartphone or other terminal installed with a CBDC wallet, and as long as their batteries are charged, a fund transfer may happen just by implementing a physical touch between the two terminals.

As already said, the trials of the DCEP already started in the China's wealthy regions, and they are expected to move soon to the poorer central and western region. As written in the Wall Street Journal, the Chinese Ministry of Commerce stated that the policy framework of the DCEP should be 100% complete by the end of 2020. As far as things stand now, Chinese

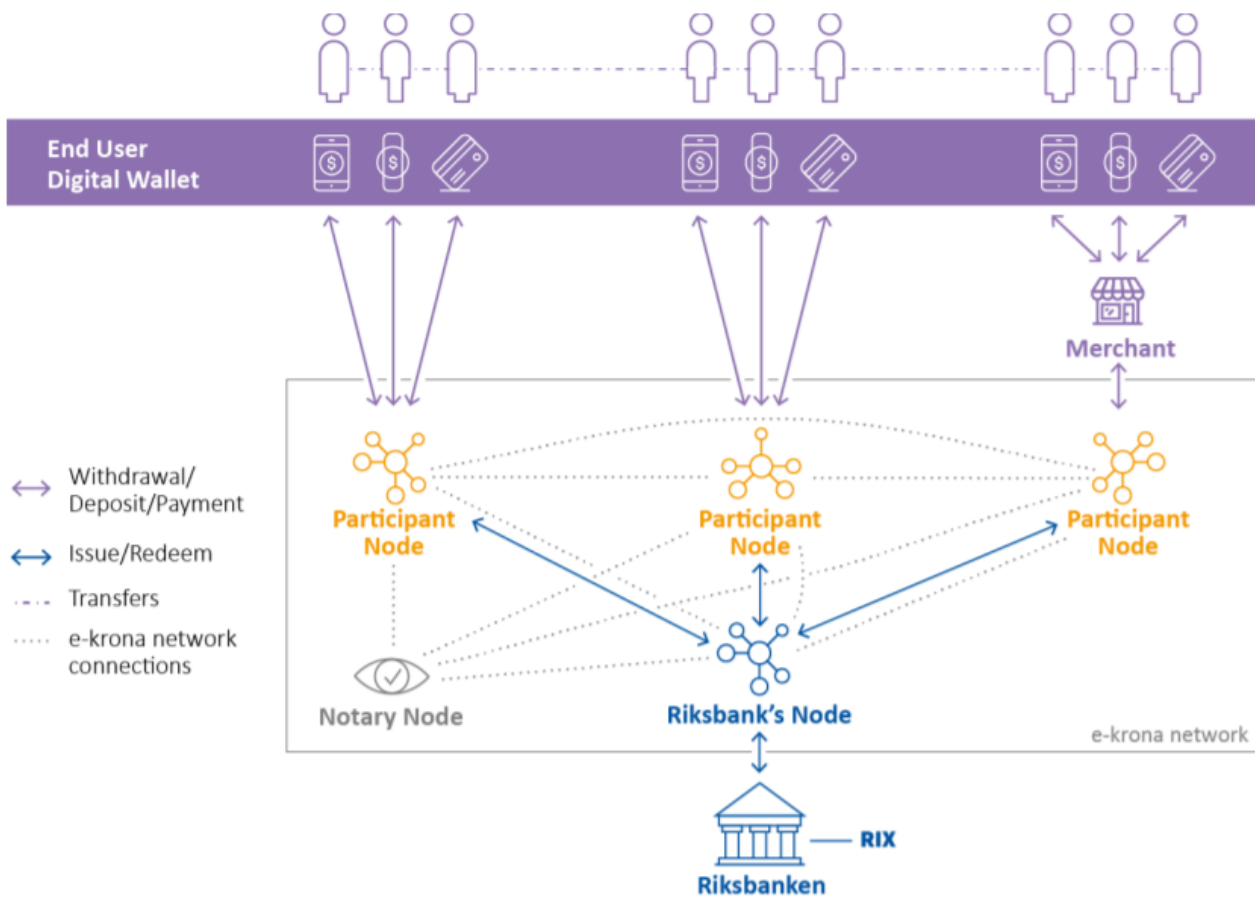
DCEP is definitely going to be the world's first central bank digital currency fully implemented.

6.2. Sweden

The leader in the development of CBDC on the European continent is Sweden and its Riksbank (Central Bank of Sweden). They are analyzing the possibility of issuing a digital currency named "e-krona" (a digital complement to cash, as stated in Riksbank's papers) and whether it could give support in the task of promoting a secure and effective payment system. What is pointed out as the main reason for the e-krona to become so relevant is the sharp decrease in cash usage in Sweden that happened over the last decade. As mentioned in the first section of this paper, Swedish households used cash for approximately only 15% of their transactions in the last year, in comparison to 30% only couple of years earlier. Riksbank hopes that e-krona would provide the general public a continued access to central bank money, as cash has done it over the last centuries, but in digital form. The risk of the krona's position being weakened by private currency alternatives should be reduced, they expect. At this point of time, Riksbank is also running a pilot project, whose goal is to create an isolated environment with a digital krona that is simple and user-friendly and where the test users shall be able to store e-krona in his digital wallet. The users of e-krona should be able to make payments via different portable instruments, such as cards or smart watches. E-krona is expected to be available 24/7/365 and payments should be instantaneous. As far as now, the technology does not provide for its offline usage, but the pilot will examine the possibility of building a new technology in which e-krona should function without the internet. In what follows, the main features of the e-krona design will be pointed out.

The test environment will be structured in two tiers, very similar to Chinese model. In the first tier, Riksbank will issue e-krona to the intermediaries. Here, intermediaries are referred to as participants in an e-krona network, such as commercial banks. In the second tier, these participants will distribute the digital currency to the end users.

Figure 4: Conceptual architecture for the e-krona pilot



Source: Riksbank (2020)

The e-krona network is private and only the Riksbank can approve and admit new participants to the network. All transactions inside the network will occur without the usage of already existing payment systems – such as RIX, Riksbank’s payment settlement system. The main technology that will be used for the foundation of the e-krona is the Corda DLT technology made by the company R3. This DLT network will be private and it will only be accessible for the participants that are approved by the Riksbank.

Making payments in e-krona should be as easy as “sending a text message”, as stated by Riksbank. The first pilot program should run until February 2021. There is currently no official decision whether the current design of e-krona will stay after the pilot program ends, as Riksbank’s stated that its main purpose of conducting the program is to increase its knowledge of a central bank digital currency and after analyzing all the results they will make a new decision on how to continue the e-krona development process.

6.3. Lithuania

On July 23rd 2020 the Bank of Lithuania (the central bank of the Republic of Lithuania) released the LBCOIN, the world's first blockchain-based digital collector coin. The project is more an experiment rather than it is an official launching of a tradable currency. "LBCOIN is based on innovative and sophisticated solutions. Therefore, it has to be tested at various angles, for example, in terms of functionality, personal data protection and resilience to cyber risks," says Pavel Lipnevicius, manager of the LBCOIN project at the Bank of Lithuania.

The Bank of Lithuania issued 24.000 digital LBCOINs. Each token is representing a portrait of one of the 20 signatories of the Lithuania's declaration of independence from 1918, and they were divided into six categories: presidents, diplomats, priests, academic, industrialists and municipal servants. Buyers of LBCOIN will then be able to trade the digital tokens between themselves, as well as to exchange the tokens for a physical silver collector coin worth 19,18 euros. The Bank of Lithuania states that their goal is not to encourage people to use these coins as means of payment, but rather to engage more people, especially young people, in coin collecting and at the same time supply them with great knowledge in the field of digital currencies.

Picture 1: Digital LBCOIN and physical silver collector coin



Source: Bank of Lithuania

LBCOIN is built on a NEM public blockchain technology, and once it is purchased, it can be stored in a NEM digital wallet on the LBCOIN's online shop. Buyers can also send LBCOINs as gifts and swap them among themselves.

To make sure, LBCOIN is not a central bank digital currency. It is supposed to help the Bank of Lithuania explore CBDCs if the project succeeds. Marius Jurgilas, member of the board of the Bank of Lithuania said that “LBCOIN is an important experiment in exploring the potential of central bank digital currencies (CBDC)”.

The whole project had been under development from 2018 to early 2020. It is expected to last for 30 months after the issuance, and when this period expires it will not be possible to exchange digital tokens for the physical silver coin and no more digital tokens will be issued. Alexandre Statchenko, one of the co-founders of the company Blockchain Partner, believes that Bank of Lithuania’s “interesting and unpretentious” initiative will fuel the debate about central bank digital currencies and deal with the “elephant in the room”, in other words deal with the important topic of CBDC.

Conclusion

This dissertation has highlighted the main implications of central bank digital currency, both from a conceptual point of view and from the point of view of its effects.

CBDC is represented as a new form of central bank money, a digital central bank liability, that serves both as a medium of exchange and a store of value. Some of the main cash-related reasons that encouraged the idea of launching the CBDC are lower costs of cash management and much less effort in conducting the circulation of CBDC. Payment systems are expected to become much more efficient due to implementation of CBDC, and they should achieve better level of security, whether the CBDC is token based or account based.

The whole process of developing the new currency is backed up by blockchain technology, that helps to record the transaction with an unchangeable cryptographic signature and that enables multiple users to make entries into a record of information. Regardless of type of blockchain (direct or indirect), it should provide system trust, better control of the system for central banks, data availability and resilience and it should provide the notion of the self-sovereign identity.

The dissertation highlighted the question of legal tender and central bank governance as two of the most important areas that central banks should consider when dealing with the legal framework that lies behind CBDC. ECB may play an important role in issuing of the CBDC, but opinions are different on the ways how should the power be given to ECB (whether through amendments of existing treaties or by other means). Overall, the legal framework behind CBDC, from a public law perspective, is not as easy as it seems at the first look.

Issuance of the CBDC brings with itself many monetary policy consequences as well as the financial stability consequences. Some of the main benefits that should be pointed out are the enhance of transparency of the central bank's monetary policy framework and its positive effect on the channels of transmission of policy rates to money market and beyond. On the other hand, financial stability consequences include the potential problem of bank-runs. Furthermore, the greater competition may rise due to the introduction of CBDC, which may lower the profitability and potentially reduce the financial stability of commercial banks.

Finally, the dissertation provided some practical examples from the real world. One of the leaders on the global level in the area of CBDC is China. They have already implemented a pilot program in four major cities across the country, and soon they expect to implement it even in the “poorer” regions. When it Comes to EU, the Riksbank and Bank of Lithuania may be considered as pioneers in the field of central bank digital currency implementation.

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