LUISS

Department of *Economics and Management*
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Chair of *International Financial Economics*

Central Bank Digital Currencies: impact on monetary and financial system.

Prof. Guido Traficante
SUPERVISOR

Prof. Mauro Visaggio
CO-SUPERVISOR

Lucrezia Leone 692151
CANDIDATE

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Introduction

The advancement of digital technology has brought innovation in many sectors, including the financial one: the development of digital currencies is an example of disruption in this context.

About that, different forms of money are currently emerging, reshaping the overall payment's system. Nowadays central banks should innovate to continue to meet the customer needs, for example through the public digital currency offering, issuing a risk-free alternative to private payment solutions instead of (or together with) cash.

The European Central Bank defines "*fiat currency as any legal tender designated and issued by a central authority, that people are willing to accept as money being well regulated and trusted*". (European Central Bank, 2012).

Even though the concept of currency as payment method remains actually unchanged, nowadays we have different ways to do a transaction are born. In particular, central banks have been under pressure to respond to the proliferation of Fintech (Financial Technology) and to the consequent developments of "stable coin" that may challenge the definition of money, the access to legal tender, even the role of central banks, the financial intermediation model and the transmission of monetary policy. The growing relevance of different digital payment's methods (e.g. SamsungPay, ApplePay, Satispay and so on) and the declining usage of cash can change the status quo and lead to more fast, cheap, secure and digital means of payment. If this is the case today, in the near future we will begin to see real digital coins, issued by central banks (but not only). Regulators, particularly in Italy, is outlining a way that can stimulate the digital currency over the physical one, due to its greater safety and speed. The latter are ensured by the blockchain as transaction enabler. This one is based on "block" that ensures the goodness of each transaction through a validator (the "chain"). The mechanism behind this structure could avoid evasion and falsification, making the payment fast and traceable. An important further application should be the "smart contract" (N. Szabo, 1994), through which two or more parties can insert a trigger situation to perform a transaction (eg. Assurance: if the client has an accident, it will be registered in the chain and will result in a payment if necessary, automatically and without bureaucracy).

Blockchain is a revolution because: "… *for the first time, there is a way for one Internet user to transfer a unique piece of digital property to another Internet user, such that the transfer is guaranteed to be safe and secure, everyone knows that the transfer has taken place, and nobody can challenge the legitimacy of the transfer. The consequences of this breakthrough are hard to overstate*" (Marc Andreessen, 2018).

In this regard, it is significant to emphasize that it has been more than 20 years since Bill Gates opined: "*Banking is essential, banks are not*"[1] and nowadays the State needs to maintain the role in the payment system, considering the trend of dramatically declining cash use.

As previously anticipated, digitalization is reshaping economic activity, reducing the role of cash and spurring new digital forms of money.

Consequently, central banks must face a difficult choice between two options: improve the existing payment solutions or issue a Central Bank Digital Currency (CBDC).

Hence, in light of these changes, various researchers are exploring different ways to find the optimal one to issue central bank backed digital currency.

The main objective of this thesis is to demonstrate that CBDC serves as a tool to meet the needs of today's society through a cost-benefit analysis, in order to meet the new need to increase monetary policy efficiency, to provide enhanced financial stability and to restructure the whole financial ecosystem.

There are several reasons that make this topic so motivating for the central bank community such as financial inclusion, payments efficiency and economic welfare. First of all, there will be several advantages for a central bank to use digital currency as a monetary policy tool, since they could bypass commercial banks and influence consumers expectation directly.

Otherwise, there are huge transaction costs like the costs of discovering the consequences of CBDC issuance to their operational aspects and the whole economic and financial system, conducting negotiations with all related parties (e.g. the commercial banks, the government and the general public), drawing up the required protocols and regulations, and monitoring the implementation and post-implementation processes.

Moreover, it's important to underpin that CBDC would be fundamentally different from private crypto assets (Bitcoin or Ether) because it would be, nothing else that money, so it will serve as medium of exchange, a means of payment and a store of value. It will be explained in particular how they hold these roles, the main differences between cryptocurrencies and stable coin and finally it will be provided an overview of the conclusions and decisions made in various countries.

According to a January 2019 report by the Bank for International Settlements (BIS) in Basel, Switzerland, at least 40 central banks around the world are currently, or soon will be, researching and

[1] Mantra for the first wave of Fintech, Bill Gates 1994.

experimenting with central bank digital currency and furthermore either IBM and Official Monetary and Financial Institutions Forum (OMIFIF) agreed that it is a great alternative to traditional money.

So, the main goal of this thesis is to analyze and casting light on the revolution/innovative disruption will carried by CBDC and to understand the possible benefits and drawbacks concern it and finally the consequences on the overall economy, in particular the implication on monetary policy. As the bank president, Patrick Harker, of Philadelphia Federal Reserve said regarding this topic: "*It is inevitable ... I think it is better for us to start getting our hands around it."*

What is money

In this section, the two main theories related to the born of money are proposed. It will be explained why something can be considered money and which characteristics and functions must complain, above all what is universally accepted and used as form of payment.

Furthermore, after having understood what is established as money, it will give a definition for every kinds of money, in order to summarize the different existing types. At the end, it will establish a link between money and trust.

Different theories of the money emergence

Through two theories, here will be clarified how money come into and developed in human's civilization. The first one, barter theory, emphasizes money function as a medium of exchange, while the second one emphasizes money's function as a unit of account and a means of payment.

Barter

Money has been part of human history for at least 3000 years. Before it, there was a system of bartering used to trade goods and services but, due to his inefficiency, it led to the emergency of a most effective mean of payment to overcome the impracticalities in barter.

This theory is mainly used by classical and neoclassical economist to explain the emergence of money. The proponents of this theory argue that the coins made of precious metals (gold, silver and copper) are the money; for this reason, they are called "*the Metallists*".

Adam Smith explained in his work "*An Inquiry into the Nature and Causes of Wealth of Nations*" (1776) that, due to the division of labor, people bartered by exchanging their surplus with their needs and wants[2]. So, this mechanism of exchange allows two parties to meet and trade goods based on what they want and what they have in order to satisfy their deficit with their surplus. However, it can be difficult to estimate and measure exactly the labor of workers and the fair value of commodities exchanged between traders. In his view, it appears evident that, one of the main functions that money must have is to serve as a measure of value.

[2] Smith argues that "*labour is the real measure of value of all commodities*".

Also Mill in 1865 emphasizes that "*the inconveniences of barter are so great, that without some more commodious means of effecting exchanges, the division of employments could hardly have been carried to any considerable extend".* In his view, money is a commodity that serve as medium of exchange.

To reinforce this concept, it's interesting to remember another scholar: Jevons. In his book, "*Money and the Mechanism of Exchange*" published in 1896, Jevons found three important difficulties that led to the birth of money as we know today. First of all, the condition of "*double coincidence of wants*" that has low probability to happen and it involve a lot of time and efforts in order to possess in surplus exactly what someone else needs. So, it is strongly needed an intermediary instrument with standardized value and accepted by both transacting parties. Moreover, it is difficult to measure the acceptable amount or quantity of exchanged goods. There was not a general rule that everybody followed but every transaction was in their own way according to the goods traded and the counterparties involved. It is necessary a common measure of value or a common denominator to make easier calculate the value of goods.

Finally, the difficulty of divide the exchange goods to meet the agreed value in the transaction. In fact, not all goods can be divided without decreasing their value proportionally. For this reason, Jevons claimed that money serves as a standard of value and as a store of value.

Milnes in 1919 summarized four money functions as *"a Medium, a Measure, a Standard, a Store*" and he explains that money is nothing but "*a third commodity, chosen by common consent to be a medium of exchange and a measure of value, between any and every other two commodities*".

Basically, for Jevons and Milnes money acts also as a standard of value and a store of value.

As a standard of value, money serves as universal language for all participating economic agents and enables to set and uniform standard prices for transacted goods and service. As a store of value, money is able to store and retain its value over a reasonable period of time; that is, its value does not decrease or vanish quickly, so it can be used for deferred spending (Hill,2018).

State Theory of Money

The State theory of Money was introduced by Georg Friedrich Knapp in 1905, to oppose the orthodox view of money of "*Metallist*", in which money is used primarily as a medium of exchange. He argued that "*money is a creature of law and a theory of money must therefore deal with legal history*"[3]. He supposed that "*tax drive money*"[4] so this latter is created by the state as a unit of account to measure and

[3] The State Theory of Money, 1905
[4] "*money is a creature of the state and a tax credit for extinguishing this debt*".

settle debts that the citizen must give to the state itself. Only what the state accepts to pay tax becomes automatically legal currency so, basically, he defined money as a unit of account to pay tax obligations with no intrinsic value, but it is always given by government.[5] As noted by Keynes said: "*the state not only enforces the dictionary (legal tender laws) but writes it (decides what is to be accepted as money)".*

Similarly, Ingham argued: "*by declaring what it will accept for the discharge of tax debt, assessed in the unit of account at the public pay offices, the state creates money*" (The Nature of Money, 2004).

As an alternative, according to barter theory, the history of the monetary system started from barter, followed by the invention of money and then the development of credit system. But they argued explaining that several Mesopotamian tables were found "*recording credits and debits, rations issued by temples, money owed for rent of temple lands, the value of each precisely specified in grain and silver*"[6] (Graeber, 2011). In short, early society started to establish a commercial mechanism by constantly creating and canceling debts and credits[7] (Mitchel- Innes, 1913), not by exchanging commodities. In this view, the function of money as an abstract unit of account (or measure of value) to measure the quantity of debts, so essentially a promise to pay.

In addition, through the course of time, many views have been developed which argue about the fact that exchange method in not the main money function, but it considered to be second to the measure of value function. To be more specific, as Ingham reported: "*money is uniquely specified as a measure of abstract value (money of account) and as a means of storing and transporting this abstract value*" (Nature of Money, 2004) . These latter views emphasized another crucial aspect of money, as said before, which underpins the differences between it and other commodities or precious metals (gold and silver) used as a method of payments: his abstractness. Money is intangible and has an intrinsic value. Or better, it is based on the trust that it has an intrinsic value, but in fact it has not cause it is only chart[8]. We return on this aspect later.

This abstraction also represents the purchasing power that is possessed by money, which "*exists independently of the goods it can buy*" (Ingham, 2004). This argumentation is based on prior literature

[5] Currencies is not backed by tangible assets but the value is given according demand and supply.
[6] He describes that the Temple bureaucrats in the ancient Sumerian society developed "*a single, uniform system of accountancy to calculate debts in silver*" (p.39).
[7] Alfred Mitchel-Innes in his two papers Money and The Credit Theory of Money (1913): "*The Credit Theory is this: that a sale and purchase is the exchange of a commodity for credit. From this main theory springs the sub-theory that the value of credit or money does not depend on the value of any metal or metals, but on the right which creditor acquires to "payment", that is to say, to satisfaction for the credit, and on the obligation of the debtor to pay his debt by the tender of an equivalent debt owned but the creditor, and the obligation of the creditor to accept this tender in satisfaction of his credit*" (p.152)
[8] *"[M]oney is the measure of value, but to regard it as having value itself is a relic of the view that the value of money is regulated by the value of the substance of which it is made, and is like confusing a theatre ticket with the performance*" (Keynes, 1983). Moreover, Schumpeter (1954): "*people, in handling money in everyday transactions, usually take a coin at its nominal value without any conscious thought of the commodity value of its materials*".

such as Keynes (1930) that considers money only an account in which debt and price and general purchasing power are named.

Just to summarize the different functions for money and the related theory, here below a scheme of what discussed during this chapter:

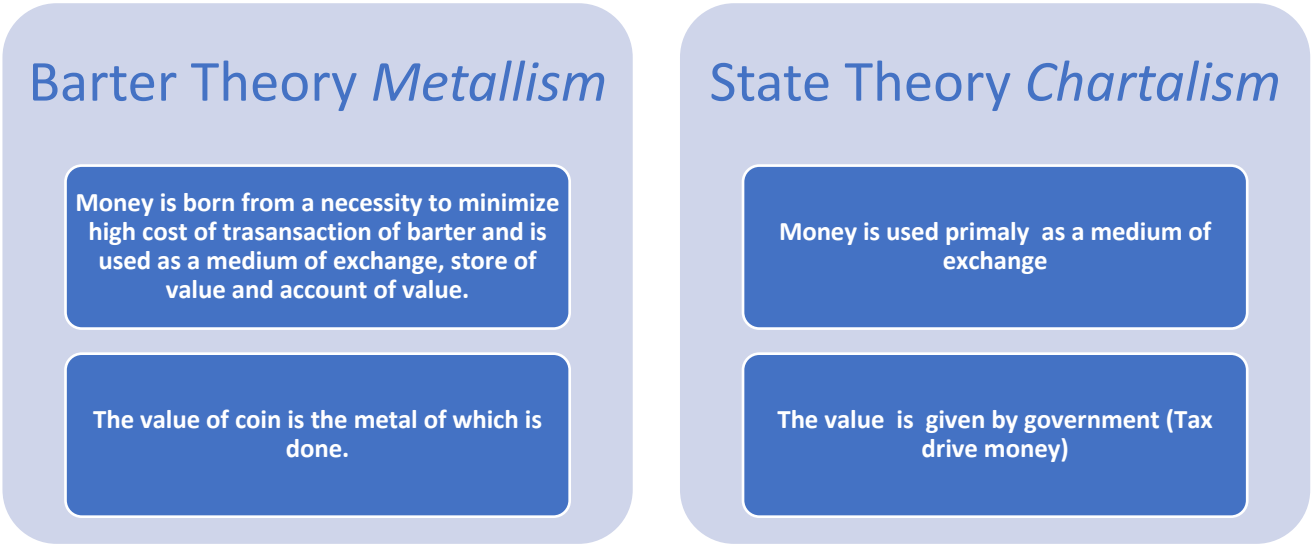

Figure 1 – Difference between theories

New challenge for theories

In recent years, virtual currencies (e.g. Bitcoin) have emerged and they are considered a potential challenge to the chartalism monetary theory. They are issued in a free and open marketplace and without any type of connection to government. Moreover, they have a high-risk of volatility and for this reason are considered speculative investment but in certain circumstance are traded and used as media of exchange. Nowadays the usage is partial, due to his lack of status as legal tender, which tends to support the "*Chartalist*" theory of the origin of money (The State Theory of Money, Knapp 1905). However, if in the future Bitcoin or other cryptocurrencies were to be accepted in markets it will be a point in favor for a market-based theory of the origin of money. This revolution could be a return to the past, because Bitcoin was born due to the necessity of alternative monetary system free from government rules and in opposition to national and bank monetary systems. So, the birth of a new monetary theory will probably happen, arising to the union of the two logics of the previous theories, having the characteristics of each of them.

To conclude this overview about different theories developed during the years, it is necessary to come back in the past, near 230 C.E.

Nearly two millennia ago Julius Paulus Prudentissimus, the emperor's chief legal advisor in ancient Rome, described the fundamental rationale for a government-issued currency that remain stable until

nowadays and he used terms familiar to modern monetary economists: "*for there was once a time when no such thing as money existed…a material was selected, which, being given a stable value by the state, avoided the problems of barter by providing a constant medium of exchange. That material, struck in due form by the mint, demonstrates its utility and title not by its substance as such but its quantity, so that no longer are the things exchanged both called wares but one of them is termed the price. And today it is a matter for doubt whether one can talk of sale when no money passes*. [9]

Characteristics

Despite the various theories from an economic system of barter to modern capitalism, everyone agreed on the fact that money makes the world go around and they usually define money as anything can be accepted in payments for goods or services with three key functions (Mishkin, 2013):

- medium of exchange;
- unit of account;
- store of value.

It can be a good, an asset, a service but the attributes to being money must be (Halaburda & Sarvary, 2016):

- divisible;
- easily measured;
- durable.

Functions of money, as said below, are related amongst themselves: if one of these three in time tends to erode, it will be searched alternative method of payments.

Unit of Account

Money should serve the role as a unit of account that facilitates the economic and financial decision for users, including the determination of wages and prices, the spending and saving decisions of customers, and the specification of financial contract.

The instrument must act as a benchmark for measuring and comparing value across goods and services (Bank for international Settlement, annual economic report, June 2018), the essential function in order to allocate successfully resources and capital in economies. The mandate of most central banks is, in

[9] Paulus served as chief legal advisor to the Roman emperor Severus Alexander (222.235 C.E.), during a period of multiple revisions to the designated purity and weight in silver of the Roman denarius. The citation is taken from the *Digest.*

fact, to ensure a stable unit of account through monetary policy. Trough prices, the rational agents or the users of money optimize their allocation of wealth and adjust their production of goods and service. So, "*prices act as an efficient way of distributing information essential for efficiently economic ordering in a decentralized manner*" (Hayek, 1948).

Medium of Exchange

Money should be able to facilitate the sale of goods and service. The seller in a transaction must accept the instrument as a means of payment with the belief that the seller can give the instrument as a method of payment for other transactions (Bank for international Settlement, annual economic report, June 2018). Furthermore, it's used to settle debts and liabilities. Moreover, money should be divisible in order to conduct transactions of any size, hard to counterfeit and able to ensure a certain grade of integrity. As medium of exchange, money facilitates the specialization labor in the economy that therefore increases economic efficiency and reduces the costs of matching agents in a transaction, by avoiding the "*double coincidence of wants*" problem.[10]

Store of Value

The instrument must preserve the purchasing power over time, in other word money has the purpose to be a storage of value. If it is susceptible to depreciation or failing to maintain its value, it would not be considered sound money[11]. In fact, economic agents can postpone their consumption by storing income from participating in economic production. As a consequence, assets such as stocks, bonds and real estate may be better alternatives in storing wealth, as holders get compensated by holding these assets and the value depends on their degree of liquidity.

In addition, it will prefer forms of money that support and maintain other public policy goals: financial integrity, financial stability and monetary policy effectiveness.

Kind of Money

In the current system, we find three types of money: Cash (physical: notes and coins), bank money on account (digital) and central bank reserve money.

[10] It's unlikely to happen that each parties hold an item that the other wants, so they exchange these items directly without any monetary medium.
[11] Bank for international Settlement, annual economic report, June 2018.

Cash

As “cash” we consider all physical money that is in circulation in the economy, as paper notes and metal coins. This money is accessible to all users (private money users, commercial banks, central banks and governments) and do not require a trusted third party to record the transfer or verify the authenticity of physical note or coin. Consequently, settling transactions with cash is usually immediate and generally does not come with transaction fees. However, it is not convenient for large transactions because it’s could be unsafe. For this reason, the proportion of cash in payment values has been declining in many economies.

Cash is typically printed, minted and supplied by the Central Bank. Instead commercial banks supplied money in response to demands from their customers, who want to exchange their bank account for cash. Banks are allowed to do this by purchasing cash for central bank reserve money, in the measure in which it can accommodate their customer’s demand.

This transaction has some costs: producing, storing and transporting physical cash to accommodate new demand, again retire periodically, replace unfit coins and notes to maintain existing supply.

Bank Deposit Account

It counts electronically recorded deposit account liabilities on the ledgers of commercial banks. This bank deposit account constitutes assets universally available for money users with a bank account. Bank money is supplied into economy when commercial banks issue loans to borrowers or receive cash deposits and decreases when account holders make debt repayments or interest payments to the bank.

Central Bank Reserve

This form of money is recorded digitally as liabilities on the ledgers of central banks. This money is only accessible to money users that hold an account with the central bank (commercial deposit banks, the treasury and foreign central banks). Non-bank companies and individuals can not have access to the accounts for payments or storage.

Commercial bank reserve money is mainly supplied by being credited to commercial banks current accounts as part of the purchase of governments bonds or certain other financial securities. Commercial banks may also borrow central bank reserve money from the central bank, which are then credited to their account. This transaction is allowed if commercial banks give some collateral in form of financial securities. Moreover, central bank can create reserve money when they pay dividend to government’s account or in exchange for government bonds. It is also possible to create new reserve money by crediting the accounts of foreign central banks in exchange for foreign currency reserve money.

Comparing these three kinds of money, it is possible to create a Venn diagram, represented below, to resume the features of each type of money.

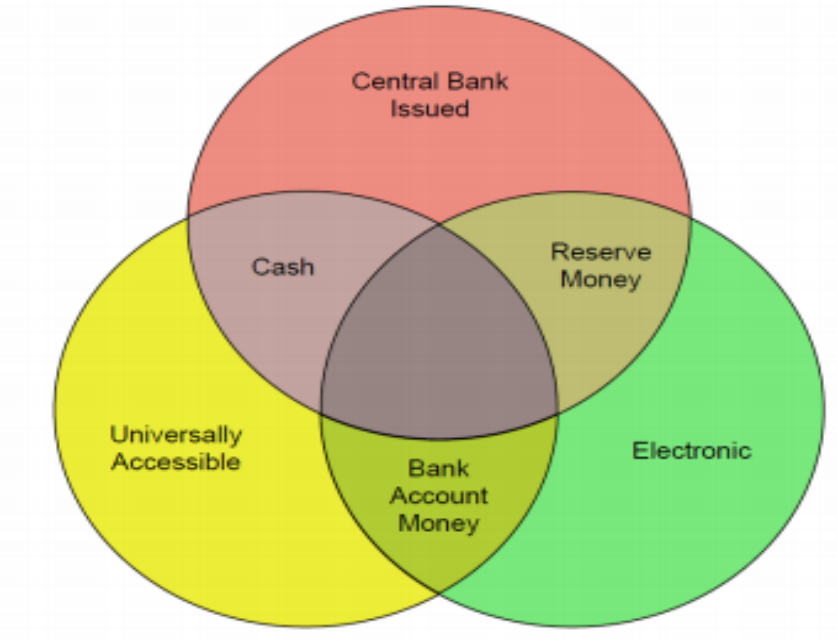

Figure 2: the features of existing money (From Ole Bjerg, 2017)

As it shows:

- Bank money and central bank reserve money are both electronic, differently from cash;
- Cash and bank money are both universally accessible, while central bank reserve money is not;
- Cash and central bank reserve money are both supplied by the central bank, while bank money is not.

  We return to this diagram later.

It is useful also outline the core features concerning their:

- **Form**: cash is the only type having a material form. For this reason, deposit money and reserve money are considered to be "accounting money".
- **Accessibility:** while there are no special limits on have deposit money or banknotes, reserves money have very limited accessibility. The only subjects that can have an account on central banks are credit institutions, commercial banks and credit unions.
- **Issuer**: each of three types of money is a liability on the balance sheet of their issuer. Cash and reserves are liabilities on the central bank's balance sheet, whereas deposit money is a liability on a commercial bank's balance sheet. Shortly, cash and reserves are issued by the central banks why are called central bank money. Deposit money is created by commercial bank when they extend credit or purchase assets.

- **Transfer Mechanism**: centralized and decentralized. In the first one, the transactions occur in a centralized ledger led by the provider of the respective payment system. The decentralized transactions require no such a centralized ledger, they take place directly between the payee and payer without any central intermediary (peer-to-peer). Transfer cash is a typical example, while the other two represent the centralized transaction.

Fiat legal tender: link between trust and money.

In this last part of the overview about the emergence of money, their characteristics and functions, it is relevant to focus on the role of trust intrinsic in money and how it's crucial to wealth economic.

As said before, fiat money represented by notes and coins does not have any intrinsic value, except the paper or metal used in the production of money. Rather, its value is a function of trust, or better, on the public trust in the government and central banks an money works and it always worked because people trust in its value.

In a barter economy, trust would be established by social enforcement in the event of malicious attempts in the exchange of good and services. Later, you could exchange banknotes issued for gold. But when barter passed out and the link between notes and gold was broken, modern money can be viewed as a special IOU (phonetic abbreviation of "*I owe you*")[12]. The agents will never trust each other, but they have trust in the medium of money. When money is issued by a central bank, people are able to trust the value of the notes and the central bank becomes a source of trust.

This means that the system is backed on the statement of a central bank or government that promise that the issued money can be used to settle liabilities in the economy. In fact, European Central Bank defines "*fiat currency as any legal tender designated and issued by a central authority that people are willing to accept as money being well regulated and trusted"*. It allows themselves to adjust the money supply in response to changes in money demand and, when it is impossible, can conduct monetary policy to ensure price stability and a sound, robust financial system. But to work it needs the trust of the agents, who need to know that received money are not rejected in future transaction and does not decrease significantly in purchasing power, doing the same end as the "*turkey inductivist*" (Bertrand Russell, 1970)[13]. It is also the reason why money became regulated and subjected to state control: due to the failure of trust in currency issued by private entities. Bank money failed because the depositors lost trust in the banks and bank runs caused severe liquidity crises that accelerated the failure of these institutions, causing huge losses to depositors and disrupting the economy. Hence, the central bank resolves this

[12] a written promise to pay back a debt.

[13] "*Domestic animals expect food when they see the person who usually feeds them. We know that all these rather crude expectations of uniformity are liable to be misleading. The man who has fed the chicken every day throughout its life at last wrings its neck instead, showing that more refined views as to the uniformity of nature would have been useful to the chicken."*

problem: money became a state monopoly and the public is protected. But what if the public don not trust anymore in central bank? The solution of this problem must be find in the new digital era in which there are blockchain and other distributed ledger technologies (DLTs) that enabling parties with no particular trust in each other to exchange any type of digital data on a peer to-peer basis with fewer or no third parties or intermediaries. Or maybe, also with their promise of fully decentralized trust, are not the answer ("*On money, debt, trust and central banking*" by Claudio Borio, 2019), as we will see below.

What is Blockchain

To understand the many opportunities that this technology can bring, for example the disintermediation of trust, it is important to know how distributed ledger technology, of which blockchain is a subset, works. In fact, blockchain is a distributed ledger technology (DLT) but not every DLT is a blockchain. First at all, I will explain specifically what they are and how DLT and blockchain work. Then it will be given a framework about cryptocurrencies that exploit this type of technology and the main characteristics.

Distributed ledger technology (DLT)

A distributed ledger is a database for storage data (or for instance money, insurance policies, contract, land titles, medical records, buying or selling goods and services) that is replicated over a peer-to peer network (P2P) and that enables multiple parties to share the database and modify data or any type of transaction in a safe and secure way even they do not know the other one. Or more specifically, "*refers to the protocols and supporting infrastructure that allow computers in different location to propose and validate transactions and update records in a synchronized way across a network*" ("*Central bank cryptocurrencies*", Sept. 2017)

As you can guess from the term "ledger", it implies a means of recording account balances or transaction history. And the term "distributed" implies the decentralized nature of this ledger spread across several nodes (devices) on a peer-to-peer network. In most cases, electronic transactions are recorded on centralized ledger, generally a trusted intermediary (e.g. the central bank, commercial banks or PayPal) that tracks account holders balance and manages the central ledger and validate the authenticity of transactions.
In this case, the ledger is, as is known, distributed across computers and other internet-connected device in separate locations globally, without the need for a trusted central authority. So, when a ledger update happens, each node constructs the new transaction, and then the nodes vote by consensus algorithm on which copy is correct. Once a consensus has been determined, all the other nodes update themselves with the new and correct copy of the ledger. This is the reason why the system is considered "trustless" system and avoid asymmetric information[14]. Agents are able to conduct transaction with strangers simply by trusting the cryptography and mathematics, as we can see below, rather than middlemen ("*The trust machine*", 2015).

[14] It can overcome the negative effects of **"***The Market for Lemons***"** and reduce harmful information asymmetries. Trust and access to information, both of which are fundamental to Blockchain. The use of a shared, immutable database that provides an unbroken decentralized record has many applications that can help level the transaction playing field.

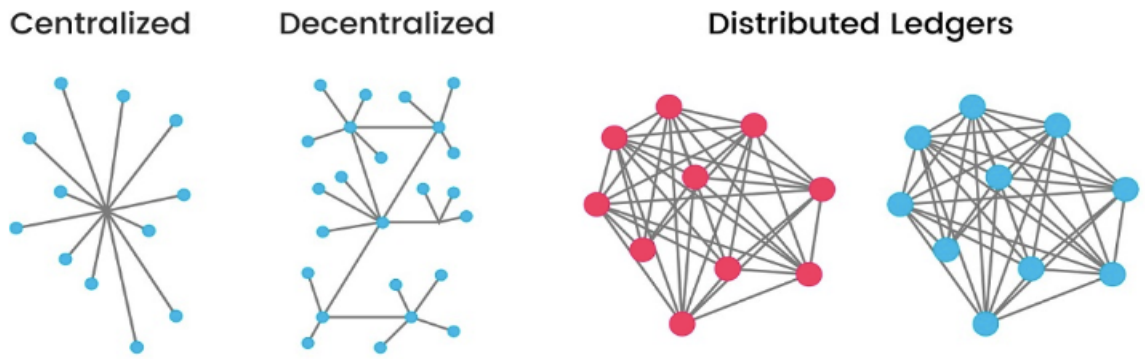

Figure 3- The difference between a centralized, decentralized and distributed ledger. (Source: Anastasiia Lastovetska, 2019).

As Figure 3 shows, users are represented by each node. In centralized ledger, the logic used is one-to-many and everything must be managed by reference to a structure, that can be authority or centralized system. The trust is in the authority that represents the center of the organization. The decentralized ledger represents the same logic of centralization at local level with "satellites" organized in their turn in the form one-to-many that relate in turn in a form that repeats the model one-to-many. There is not a large "central" subject but many. In this case confidence and trust are delegated to central subjects, closer but still centralized. The real change, as you can see, is represented by the distributed ledger, that is by a real and complete logic distributed where there is no longer any center and where the logic of governance is built around a new concept of trust between all the subjects. No one has the possibility to prevail and the decision-making process strictly passes through a process of building the consensus. Red points are anonymous so they have a copy of the ledger and participate in confirming transaction independently while the users in blue are not anonymous and permission is required for them to have a copy of the ledger and participate in confirming transactions.

Blockchain

For cryptocurrencies (including the most famous one, the Bitcoin), the ledger used is the Blockchain that is a form of DLT data structure that:

- Records transactions across a distributed network of computers;
- Combines data about the subject-matter of each transaction with data about the transferee and transferor in a "block" such that these blocks form a "chain";
- Uses cryptographic means to prevent tampering with the chain;
- Relies on nodes in the network to verify transactions, often through some kind of game-theory informed incentive mechanism.

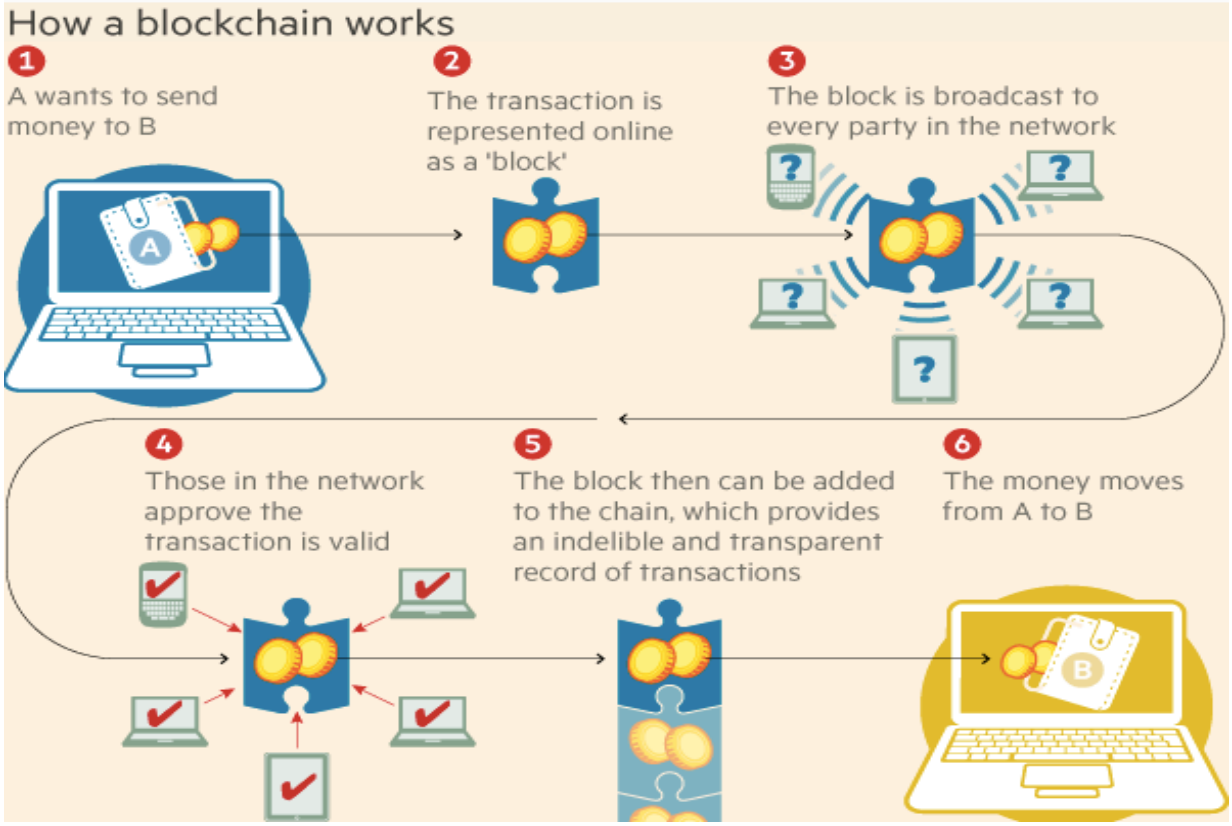

Figure 4- How a blockchain works (Source: "Technology: Banks seek the key to blockchain, Financial Times, 2015")

As said before, transactions are recorded in batches, or "blocks" with new blocks being "chained" in order to amend the existing ledger with additional transactions. This process of clearing and settlement can happen in every part of the day and it all occurs mathematically, with a marginal human intervention.

Shortly, we can say that blockchain are distributed ledger technology characterized by a registered set up and structured in order to manage transactions within a chain of blocks. The blocks are connected and protected

by cryptographic tests. To generate news blocks, which are in chronological order, the participants of network must resolve an expensive and intensive computing activity, called mining.

But who is accountable for the validation of each transaction?
Responsibility for verifying the validity of new blocks is shared by nodes, so every computer belonging to the network, through a consensus mechanism with cryptographic tools and protocol rules. Shortly, a blockchain is run through a distributed network of participants who do not necessarily trust each other but follow the same rules (consensus mechanisms). When validated, this transaction will be bundled with others into a new "block" and added to the blockchain. The whole process ensures that each block is created in a way that irrefutably links it to the previous one and the next one, forming a chain of blocks or blockchain. In this way, the database or ledger is constantly updated and synchronized storing the records of all transactions ever executed across a network.

Regarding the verification process, Blockchain can be classified in two system:

- Permissionless: The network is unrestricted and everyone is motivated to take part in the verification process as nodes can do it;
- Permissioned: the node acting as verifiers are chosen by one or several central authorities.

Furthermore, based on who can read the ledger, a blockchain can be:

- Private: when only authorized entities have access on the ledger;
- Public: when anyone can access a whole blockchain and read its contents.

We can distinguish four major blockchain types: public permissionless, public permissioned, private permissioned and private permissionless blockchains.
In a public permissionless blockchains everyone can participate in the blockchain's consensus mechanism, make transactions and see the blockchain's transaction history. While in a public permissioned blockchains, everyone can transact and see all transactions but a restricted number of nodes can participate in the consensus mechanism. The private permissioned type restricts the ability to transact and view the transaction to only the participating nodes in the system, furthermore, the architect or owner of the system determine who can participate in the blockchain system and which nodes can participate in the consensus mechanism. Instead, the private permissionless system is restricted in who can transact and see the transaction while the consensus mechanism is open to everyone.

Regarding the mechanism of consensus, the best-known is '*proof of work*' (PoW) which relies on the computational or processing power of the nodes or computers (called 'miners' because they make "mining" and so they do the validation) to solve a complex mathematical puzzle as quickly as possible. The miners are

incentivized by transactions fees and block rewards but there are some electricity consumption and hardware investment to make extremely costly to attack the network. The alternative consensus model is "*Proof-of-Stake*" (PoS) that don't require an excessive electricity consumption in mining or specialized computer hardware. Instead, it implies that a person may mine or validate block transactions on the basis of how many coins he or she holds. Miners place an amount of cryptocurrency in a staking pool and the protocol chooses which node is granted to validate based on probabilities relative to coins at stake.

It is important to underpin that blockchain is just one type of distributed ledger. In fact, this latter is a sequence of blocks, distributed ledgers do not require such a chain and do not need proof of work, it is only a type of database spread across multiple sites, regions or participants. That is why even if all blockchains are distributed ledgers, not all distributed ledgers are blockchains. While a DLT gives to the users and participants transparent information of transactions, minimizes the time of transaction and increases back-office efficiency and automation, blockchain it is more useful for financial transactions, cutting down on operational inefficiencies (which ultimately saves money). In fact, blockchain provides greater security because it offers a way to securely and efficiently create a tamper-proof log of sensitive activity.
This could include anything from international money transfers to shareholder records. So financial processes are radically upgraded to offer a secure, digital alternative to settlement and clearing house processes avoiding bureaucratic, time-consuming, paper-heavy and expensive proves. When you write data to a blockchain, it gets etched on the network. Similarly, when you have a series of transactions over time, you gain an accurate and immutable audit trail: very useful for financial audits.
Furthermore, having data stored in a place where no one can own, control it or change it, gives benefit avoiding errors or frauds.
Let us see some major features.

Features

1. Decentralization.

There is not a central entity that controls the system but everyone follows a set of rules (or consensus mechanism) to verify, validate and add transactions to the blockchain. Consequently, there is no central point of failure and the existence of multiple and distributed nodes makes the system very resilience and very difficult to attack.
However, public and permissionless blockchains can handle a limited number of transactions and the Pow, as said, means high energy consumption. Moreover, it can bring attacks if a group of participants controlling a majority (50% + 1%) of computational resources. In a permissioned system that thing do not happen cause a preselected group of participants have the power of validation. But this lead a weaken of the concept of decentralization and it can be considered centralized or semi-centralized model.

2. Tamper-resistant.

It is extremely difficult to change or delete the record of transactions and every modification is visible to everyone. Only if there are the consensus by the network of participants there will be a possibility to delete or change the history of transactions. If it does not happen, there is a unique temper-resistant version of the records. Nevertheless and despite its decentralized nature, the drawback is that a group change the records or reverse transactions could happen. And this is the reason why tamper-resistant does not involve the characteristics of immutability and unchangeability, even though it is very hard to change.[15]

3. Transparency.

Everyone with an internet connection to the network has the same rights to access and update the ledger. All transactions are transparent and visible, previous consensus by everyone belonging to the network. Furthermore, all participants can have access to the ledger and this brings to have high trust in the network.

4. Security.

The key advantage of a blockchain is keeping track and verifying information in a secure way. Data (such as detail about a payment, a contract, transfer of ownership and so on) is linked publicly to a certain date and time, so no one can modify what has been recorded and time-stamped. This aspect can be very useful to know exactly when a specific transaction was made, or to certify that data existed at a specific moment in time. Furthermore, to understand better what it means to be a safe system, it is necessary to explain another important characteristic of blockchain: the keys.

Participants have a distinct identity based on a combination of public and private keys: public keys are widely shared with the others in the network, while private keys are kept secret. For instance, messages or transactions encrypted with a private key can only be opened by recipients with the corresponding public key that is previous shared by the sender. If a message is encrypted with a public key it can only be decrypted by a specified recipient using her or his private key. This aspect will be address in depth during the lecture.

5. Smart contracts.

"*Smart contracts are computer programs that are capable of carrying out the terms of agreement between parties without the need for human coordination or intervention*" (Buterin, 2015). The idea of self-executing contract was presented by Nick Szabo in 1997, in the article "The Idea of Smart Contracts". He exemplifies

[15] *"Changing the record of transactions via consensus has happened before. One of the most controversial cases was 'the DAO hack' in which the theft of funds was restored through a community decision to split or 'fork' the underlying record. This case generated wide debate as to what trust means in blockchain systems. It laid bare the importance of governance because, in the end, blockchains still rely on a set of agents (developers, miners, users and other participants) who have specific roles and can intervene in specific moments when it is perceived (or required by law) to fix problems, upgrade the system or reverse unintended consequences*".

the idea of a vending machine to figuratively present smart contracts. Everyone who has the money to pay for a product can buy it for the given price and the product and the money is secured from intruders by the features of the machine. As is well known, trust is the core of blockchain, intrinsic in his system. So, it provides a foundation for applications. The agreements of the contract can be recorded and validated into a blockchain which can then automatically execute and enforce the contract under "if-then" instructions: if something happens (for example if you pay) then certain transactions or actions are carried out (you will have the product). This brings to remove the need for a trusted third party to function as an intermediary. The way in which transactions are verified and added to the blockchain guarantees that conflicts or inaccuracies are reconciled and that in the end there is only one valid transaction (no double entries).

Future applications

For these intrinsic characteristics, some potential benefits of blockchain in international trade within 10-15 years could be:

- Reduce cost of trading;
- Improve the efficiency of cross-border payments and the ability to resolve stuck transactions;
- Improve speed, efficiency and transparency in debt markets;
- Give small firms access to the global market;
- Simplify process for letters of credit and trade finance;
- Improve monitoring and regulation of markets;
- Secure and share data and records, such as transaction history;
- Strengthen intellectual property rights;
- Improve governance and social outcomes in developing regions.

Next challenges

After having explained the main features of blockchain, it is also important recorded the challenges remain until unresolved:

1. Limited scalability and performance of public blockchain:
   Mainly related to the low volume of transactions or the high energy consumption when deploying PoW (Proof of Work) consensus mechanisms.
2. Potential attack:

Other threats can arise from potential collusion from a majority of participants which could overrun the network (50 % +1% attacks) or from the high dependency of running the network on a limited number of participants[16].

3. Key management:

   A major source of security vulnerability also lies in the responsibility of keys, which can be as simple and serious as losing a phone or a back-up of the credentials.

4. How to safeguard personal, sensitive or confidential data:

   Transparent data on a blockchain might be a problem when specific data sets are not meant to be publicly available, or need to be changed due to errors, inaccuracies or other problems in the original data entry (European Commission, July 2019).[17]

Let resume the pros and cons, already mentioned, of this type of technology.

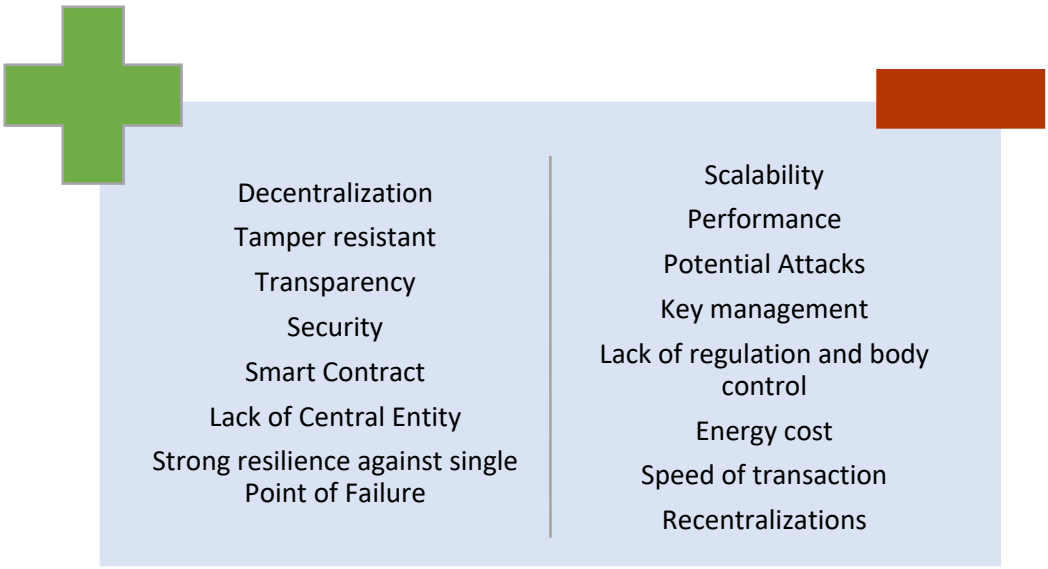

Figure 5- Pros and Cons of blockchain.

[16] In, for example, permissioned blockchains.

[17] "*Potential conflicts between specific blockchain architectures and the EU's GDPR warrant a wider debate.*"

Cryptocurrencies

The legislative authority defines them as follows*: "Virtual currencies means a digital representation of value that is not issued or guaranteed by a central bank or a public authority, is not necessarily attached to a legally established currency and does not possess a legal status of currency or money, but is accepted by natural or legal persons as a means of exchange and which can be transferred, stored and traded electronically and "custodian wallet provider" means an entity that provides services to safeguard private cryptographic keys on behalf of its customers, to hold, store and transfer virtual currencies.*[18] (Directive (EU) 2018/843 of the European Parliament and of the council)

A cryptocurrency is a form of digital currency used as a mean of exchange within a distributed network of users. Unlike traditional banking systems, these transactions are monitored through the use of blockchain and can take place directly between participants (P2P) without the need for intermediaries. The term "crypto" is referred to cryptographic techniques (mining process) used to protect and validate every block and ensure secure financial transaction.

Basically, cryptocurrencies are:

- Privately issued: unlike bank deposits for instance, they are not liabilities and cannot be redeemed.
- Digital: similar to electronic money (e-money[19]) issued by commercial and central banks and are also fiduciary (no intrinsic value).
- Exchanges via cryptocurrencies are peer-to-peer, so there is not central authority needed for the settlement of digital transactions between counterparties with a DLT technology that avoid "double-spending-problem".

Digital currencies, based on its underlying technology and how it is managed, can be distinguished further into two types:

- Centralized: issued and managed centrally by a company within a closed system and its usage is usually strictly controlled and monitored by the company.[20]
- Decentralized (or distributed): is not issued by a specific company or entity and utilizes an underlying decentralized technology (DLT) to facilitate transaction.

[18]This directive thus describes the cryptocurrencies within a text designed as a legal basis for combating money laundering and terrorist financing.

[19] E-money: "*value stored electronically in device such as a chip card or a hard drive in a personal computer*" (Committee on Payments and Market Infrastructure, 2015). This type of money is legal recognized so it's denominated in the same currency as central bank or commercial bank money and can easily be exchanged at par value for them or redeemed in cash".

[20] For example, PokèCoins in Pokèmon Go game that can be used to purchase in-game items.

Consequently, advantages are:

- Anonymity of transactions ensured by decentralization.
- Private issuance is decided not by a political institution but by an algorithm that can avoid discretionary decisions that can lead to too much inflation. This will increase transparency (for anyone able to read the algorithm) and the predictability of their "monetary policy". But this can be also a disadvantage because discretionary decision-making allows for flexibility to deal with shocks.
- Truly global and easily accessible currency that could facilitate global trade due to the fact that is not linked to a particular jurisdiction.

At least 2221[21] cryptocurrencies exist, but a vast majority is represented by Bitcoin, as you can see from the chart n°6.

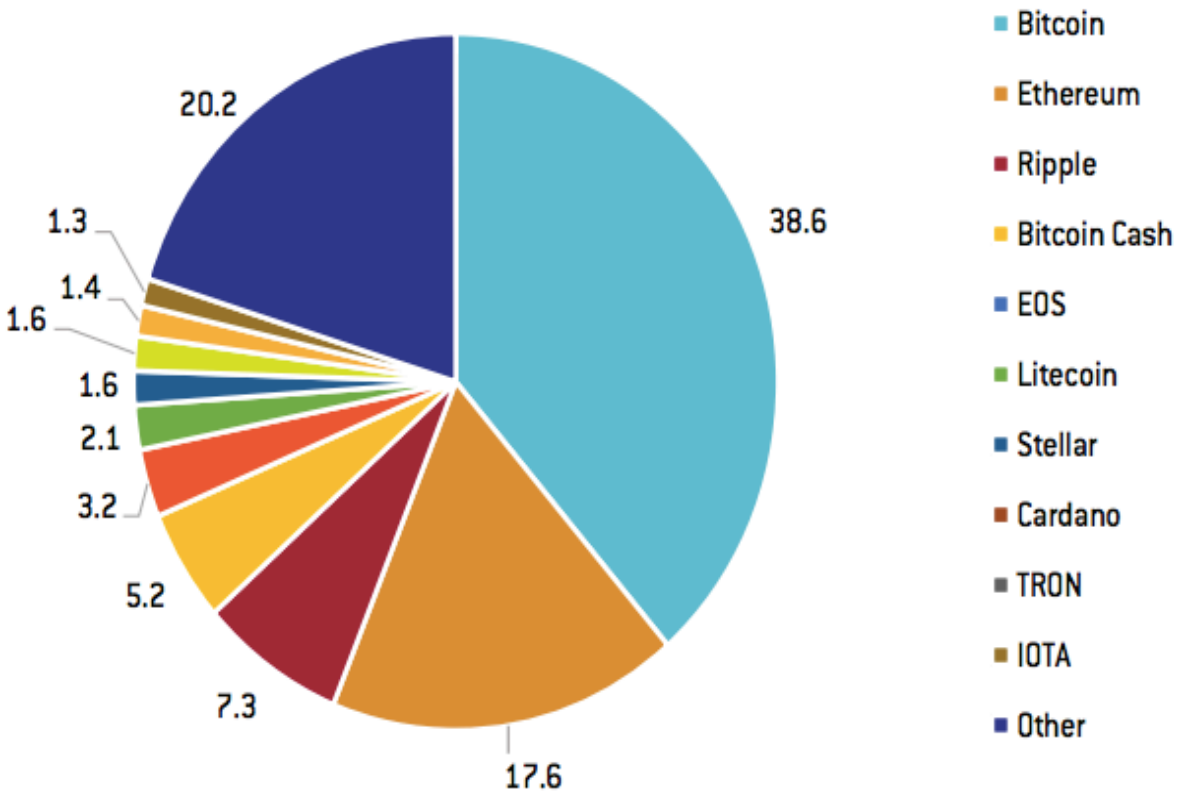

*Figure 6– market shares of cryptocurrencies (*Bruegel based on coimarketcap.com, May 2018, in %.)

Bitcoin

To explain better how blockchain and DLTs work it is important and necessary to mention how Bitcoin works and looking deeply into blockchain implementation[22].

[21] From Coimarketcap, June 2019.
[22] Note is that Bitcoin is only one of the several applications of this technology.

Bitcoin is a cryptocurrency system created in 2009 by Satoshi Nakamoto, a pseudonym of the person or group of people who designed and implemented the system.
However, Bitcoin has precursors called *ecash, hashcash, B-Money, Bit Gold, Anonymous Electronic Cash*. Despite this, previous experiments have always been blocked or by exogenous problems, namely governments that have opposed and shut down central servers, or endogenous, that is software with structural limits that could not guarantee in depth the promised service.
The term Bitcoin, with a capital B, refers to the underlying technology and to the network, while bitcoin indicates the coins generated and spent inside the system. Bitcoin was the first cryptocurrency created and, following its implementation, there are now more than 2 000 different cryptocurrencies[23]. It is not a coincidence that Bitcoin was introduced in the aftermath of the Lehman Brothers' crisis. Precisely on third of January 2009 the source code of Bitcoin was released within which a message that criticized the current financial system that was to collapse and need the government bailout: "*Chancellor on brink of second bailout for banks*".

Bitcoin is a digital currency: all coins are created, spent and transferred digitally inside Bitcoin's ecosystem. It is simply a permissionless distributed database which lists accounts and money like a ledger, where everyone connected to the bitcoin network shares the same ledger (Driscoll, 2013). What makes it special is that there is no central entity creating coins and verifying transactions. Instead, the entities or users who are part of the Bitcoin network take on this role. It demonstrated how it was possible to solve the problem of digital-double-spending[24] using a global network, without borders, open, decentralized and without a central authority.
In fact, network participants compete to solve cryptographic puzzles necessary for validating a new block (through a proof-of-work consensus mechanism). As economic incentive, the first ones succeeding receive newly issued units of Bitcoin ("*Director of Federal Reserve Bank Operations and Payment System*", January 2019). This mechanism incentive may help nodes to stay honest, because "*if you pay a person to be honest and efficient, then he will be no more inefficient and dishonest"* (Satoshi Nakamoto).

How do Bitcoin Transactions work?

All users participating of the network are represented by addresses, a sort of bank account number but with the important difference that the account holder cannot be identified, at least not so easily. In this way Bitcoin accounts are pseudonymous. Addresses are created using public key cryptography. Each public key has a corresponding private key that allows users to make a transaction. Moreover, each user owns many Bitcoin addresses and to facilitate the use of multiple address, a specialized software called "wallet" is used.

[23] As of February 2019.
[24] The same digital currency can be spent more than once. In other words, a transaction uses the same input as another transaction that has already been broadcast on the network.

The wallet handles all the user's addresses, and thus all the corresponding key and automatically combines accounts in order to perform transactions. In this way, it is not possible to lose cryptocurrencies but only the private key that allows users to have access to those cryptocurrencies.
When any users want to do a transaction and he publishes his intention, the nodes scan the entire bitcoin network to validate that he has enough bitcoin and he hasn't already sent it to someone else, putting both private key and transaction details into the Bitcoin software. The network then confirms that the user has not previously spent the bitcoin by running through his address history (public key). After that, transaction get included in a "block" which gets attached to the previous block and it cannot be tampered or undone because it would mean redoing all the blocks that came after. This occurs because each block includes, as a part of its data, a hash of the previous block. That is what makes it part of a chain.

A hash mentioned before is produced by a "hash function", which is a complex math equation: algorithm. A hash function has some very important attributes:

- For the same input, the output will always be the same;
- There is a different output for a different input;
- The output does not reveal any information about the input data.

Shortly, through this cryptographic function it is possible to transform data of arbitrary length into a fixed-length string. As said before, some nodes are mining nodes, or miners. They solve a complex mathematical problem including the answer (a number) in the block. This number combined with the data in the block and passed through a hash function, produces a result that is within a certain range. The hash function makes it impossible to predict what the output will be and there is no way of knowing which number will work. The miners, guessing at random, keep trying until someone finds the mystery number and applies the hash function to the combination of that guessed number and data in the block. The first one that finds the number earns all the transaction fees that are included in the transactions inside the new block. The reward and the transaction fees area incentive for miners to keep mining, even after all the bitcoin are in circulation. This process of mining or the consensus algorithm is used by Bitcoin to ensure trust in a non-trusted network.

Characteristics

Blockchain technology started with the development of Bitcoin, which was created with the aim of introducing a convenient alternative form of currency not subject to the control of a state authority.
Many consider the Bitcoin similar to the gold, in fact, often is defined "digital gold".

Moreover, it is considered a medium of exchange because there is high expectation to use bitcoin in other exchanges, due to its intrinsic characteristics: scarcity, fungibility, incorruptibility, homogeneity. These characteristics, unlike the real gold, are guaranteed by the technology on which it is based, so the blockchain. Bitcoin is a DLT for the storage of information on the exchange of ownership of a digital representation of value. But the address does not contain cryptocurrencies.

Blockchain is only a ledger in which there is a history of all transaction. Physical money does not exist and it is not stored anywhere. The coins are only accounting item and the final balance is made by calculation between all transaction of an address. [25] Moreover, unlike the fiat currency, its value is not supported by the status of legal tender but it is solely determined by the trust that each person holding it has on the underlying technology that does not allow double spending and so it accepted by other economic actors as a means of payment.

Advantages

1. Blockchain based cryptocurrencies do not need a central authority. This enables users to send transactions and exchange crypto coins simply by creating an account. This process can be also done by intermediaries such as cryptocurrency exchanges and custodian wallet providers.
2. The transaction is considered verified through the consensus mechanism in place and depending on the blockchain implementation, confirmation may be notified within a range time limit. It can make a difference for example for merchants since a credit-card payment will be validated after a few days.

Limitations

1. Using cryptocurrencies for real-time purchases involve that the merchant will have to wait for about an hour to be sure that the transaction has gone through.

2. The absence of a monetary authority and a lender of last resort make cryptocurrencies highly volatile in the face of speculative activities and harder to recover from crises and exposes them to a long-term deflationary dynamics.

There are many justified doubts that these permissionless cryptocurrencies cannot function as sound money. In fact, Bitcoin failed to satisfy the classical criteria of money that we mentioned previous. Although Bitcoin remains the most popular cryptocurrency and is accepted as form of payments sometimes, but "*the worldwide commercial use of bitcoin remains miniscule*" (*Is Bitcoin a Real Currency*?" by David Yermack, 2013).

25 In our monetary system the 92% of all money in circulation exists only as an accounting item in computer systems (Source: The Economic Times, TechLife "Weird but true facts about technology" 2016).

Bitcoin performs poorly as a unit of account since bitcoin-based quotes for prices of ordinary goods and commonly extend to "*four or five decimal places with leading zeros, a practice rarely seen in consumer marketing and likely to confuse both sellers and buyers in the marketplace*[26]". Even then, due to its high volatility it does not work as a store of value and it can represent a problem because the use of bitcoin and other cryptocurrencies as a medium of exchange has increase without pass through central banks and commercial banks. To many observers, "*cryptocurrency's extreme fluctuations and growing number harken back ominously to the era of wildcat banking, when state banks circulated their own currency that too often had dubious worth*" (Robert C. Hockett, December 2018) [27]. This excess volatility and in long term deflationary push means that bitcoin, and many of its current alternatives, should probably be considered somewhat of a failed experiment in terms of reaching their stated purpose of providing a reliable and stable currency.

As it is shown below, the trend of Bitcoin price index since 2014.

As you can see, it shows a jump in 2018 and a trend of highest volatility since the last two years[28].

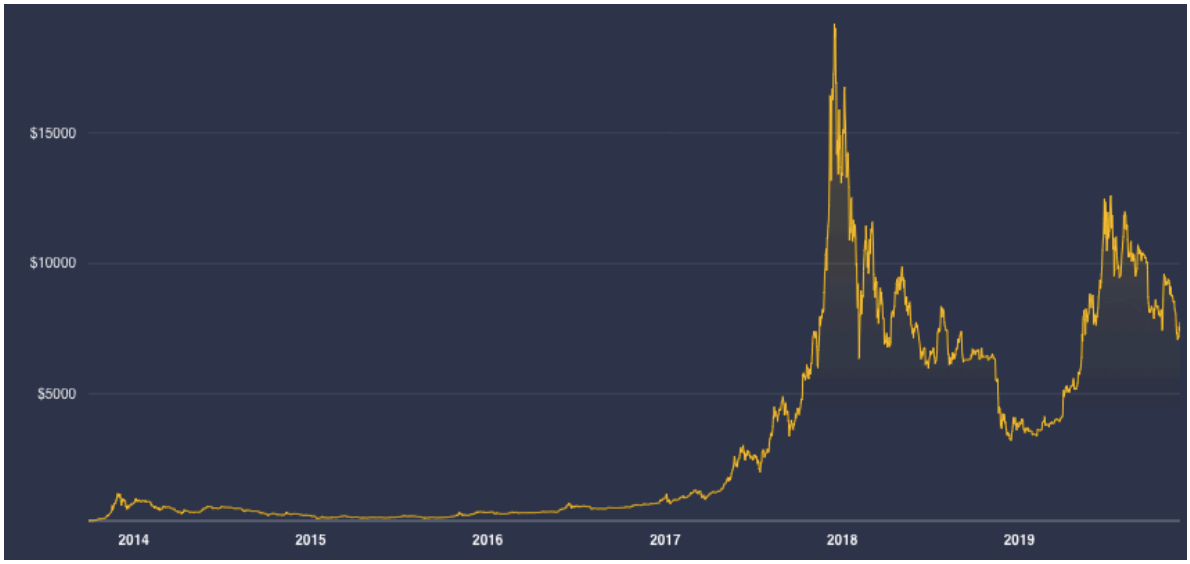

Figure 7- Bitcoin price index from 2014 until nowdays (Source: "*Coindesk*", 2019)

[26] That said, there have been proposals to introduce a millibitcoin (mBTC) to better account for pricing of conventional goods. "*It's time to change the way we measure Bitcoin*".

[27] "*Money's Past Is Fintech's Future: Wildcat Crypto, the Digital Dollar, and Citizen Central Banking*" by Robert C. Hockett, December 2018.

[28] Even though bitcoin may still be the rock star in this asset class, it appears to be aging fast. Bitcoin had the lion's share of weekly trading volumes, measured in US dollars, as late as 2015; however, its share fell below 50 per cent in 2017 as other cryptoassets gained market share. Trading in tokens (cryptoassets that do not have their own blockchain) and altcoins has increased to around the same volume as bitcoin, while ether is holding its own.

As a result, they can be considered more an asset than a currency, because there are expected yield return. For this reason the ECB has defined it as "*a new type of asset recorded in digital form and enabled by the use of cryptography that does not represent a financial claim on, or a liability of, any identifiable entity*" (ECB Crypto-Asset Task Force (2019).

Here we summarize all the differences between a legal tender currency and a bitcoin.

Difference between fiat digital currencies and cryptocurrencies.

1. Decentralization. As mentioned before, no single institution controls the Bitcoin network. It is maintained by a group of volunteer coders, and run by an open network of dedicated computers spread around the word. It solves the "double spending problem" of electronic currencies through combination of cryptography and economic incentives. Since there is not a single authority bitcoin is not a liability of anyone. In electronic fiat currencies, this function is fulfilled by banks, which gives them control over the traditional system and represent liabilities on the issuer's balance sheet. With Bitcoin the integrity of the transactions is maintained by a distributed and open network.

2. Limited supply. Fiat currencies have an unlimited supply and central banks can issue as many as they want and can attempt to manipulate a currency's value relative to others. On the other hand, with bitcoin the supply is tightly controlled by the underlying algorithm. A maximum quantity allowed of bitcoin is around 21 million. This makes bitcoin more attractive as an asset, because if demand increases the value consequently rises but not as a role of money. This could lead a deflation: when bitcoin rises until the maximum quantity, inflation will fall to zero and miner could earn only from fees of transactions.

3. Pseudo-anonymous. Sender of traditional electronic payments are usually identified, users of bitcoin in theory operate in semi-anonymity. Since there is no central validator, users do not need to identify themselves when sending bitcoin to another user. When a transaction request is submitted, the protocol checks all previous transactions to confirm that the sender has the necessary bitcoin as well as the authority to send them. Each user is identified by the address of his or her wallet so the system does not need to know his or her identity. But if it is strictly necessary, the identity users can be identify. This makes bitcoin not an ideal currency for criminals, terrorists or money-launderers.

4. Immutability. Bitcoin cannot be reversed, unlike electronic fiat transactions. If a transaction is recorded on the network, cannot be modify anymore.

5. Divisibility. The smallest unit of a bitcoin is called a satoshi. It is one hundred millionth of a bitcoin (0.00000001), around a hundredth of a cent. This lead to make transaction that with traditional electric money cannot.

Today's fiat currencies issued by central banks perform well all three traditional function of money. This because, central banks provide an elastic supply of their currencies to fulfil their price stability mandates in an accountable but discretionary institutional setup: inflation targeting. In a jurisdiction where independent central banks have a price stability mandate and fulfil it using many tools (as short-term interest rate changes, asset purchases, expectation management) currencies are a reliable store of value, predominant medium of exchange and unit of account.

For cryptocurrencies, to replace official currencies they would have to overcome a triple challenge:

1. The supply of cryptocurrency would need to act as an instrument that affects the economy;
2. In the presence of fractional reserve banking, the supply would need to respond to liquidity crises and act as a lender of last resort in order to safeguard financial stability;
3. There would need to be a system of checks and balances to keep the agent (i.e. cryptocurrencies issuer) accountable to the principal (i.e. society) which is not possible because cryptocurrencies are automatically and privately-issued.

For these reasons, official currencies controlled by inflation-targeting independent central bank still appear to be a far superior than cryptocurrencies to provide the money functions.
The condition to fulfil the functions of money must be price stability and a sufficiently large network of users. There are already cryptocurrencies called "stable-coin" that are trying to solve these problems, improving supply protocols to limit the volatility.

Stablecoin

In this context there is undoubtedly a need for a guarantee of stability as well as an effective medium of exchange, unit of account and store of value. Among the three functions of money, being a good store of value appears to be a necessary condition for other two and if the value is not relatively stable over time, it will not widely used.
Stability in the value of the currency requires that supply follows demand in a way that avoids both high inflation (rapid loss of value) and deflation (rapid gain in value).
If it were possible to achieve stability, many countries that are living in crisis due to unstable economy and severe political regime could finally have access a reliable monetary system. What could be the solution in a

system where not even the dollar can fulfill this role (just thinking about the war, crimes, fractional reserves and other facts that affected the price of American dollar)?

In this view, attempts to create a stablecoin can be defined as attempts to create a "fiduciary currency", exploiting the blockchain that provided us the tools to have a new sense of trust in each of us.

The current attempts to create fully guaranteed stablecoin remember the early stage of development of any new currency system.
To define stability, the value of the currency must be linked to another exchange medium considered stable, which is generally another currency that is not volatile. For example, let us think about Gold Standard: at the beginning there was 1:1 coverage with gold and gradually decreasing until it was completely eliminated when confidence in the monetary system was firmly established.
But this anchorage, or fixed exchange rate, with everything that is considered reliable (e.g. gold, real estate, commodity) is not sufficient and do not evade the risk of single point of failure.

We can find three different type of stablecoin initiatives:

1. Stablecoin fiat/ asset-collateralized ("off-chain collateralized stablecoins"): supported 1:1 with real assets such as dollar, gold or oil. In this view, user still have to trust a third party that guarantees it, like the traditional payment infrastructure.

2. Crypto-collateralized stablecoins ("on-chain collateralized stablecoins"). Cryptographic resources are used as a guarantee of stability. Risk are mitigated by using different currencies with overcollateralization to cover volatility price with a ratio 1:1,5. The need to trust a third party is eliminated but requires over-collateralization economically ineffective, blocking a huge amount of cryptographic resources.

3. Uncollateralized stablecoins ("algorithmic stablecoins"): stability is only the right combination of supply and demand. Instead to support the currencies with resources, it creates "algorithmic central bank", which manages supply and demand according to rules coded in a Smart Contract, like traditional banks but in an encrypted environment. If price increases, more coins are minted, if price decreases, some of the existing tokens are repurchased and burned. In this case, it might be decided to not peg a currency to the US dollar but rather to some economic measures of life stability (e.g. index of consumer prices). In this way, they avoid not only crypto-volatility but also the collapse of traditional currencies. In this sense, uncollateralized stablecoins could radically change the world, becoming more reliable than current legal currencies. There are two main problems related to this model:

- Blockchain is not able to take data from the outside, and this data are necessary to price the stablecoins;
- This model is based on the continued growth of the system to cover price differences and it will work until the max supply is achieved.

Using the criteria mentioned before, a "crypto-cube" can be set up:

1. On right horizontal axis: the existence/absence of an issuer that is responsible for satisfying any attached claim;
2. On left horizontal axis: the decentralization/centralization of responsibilities over the stablecoin initiative;
3. On vertical axis: what underpins the value of a stablecoin and its stability in the currency of reference.

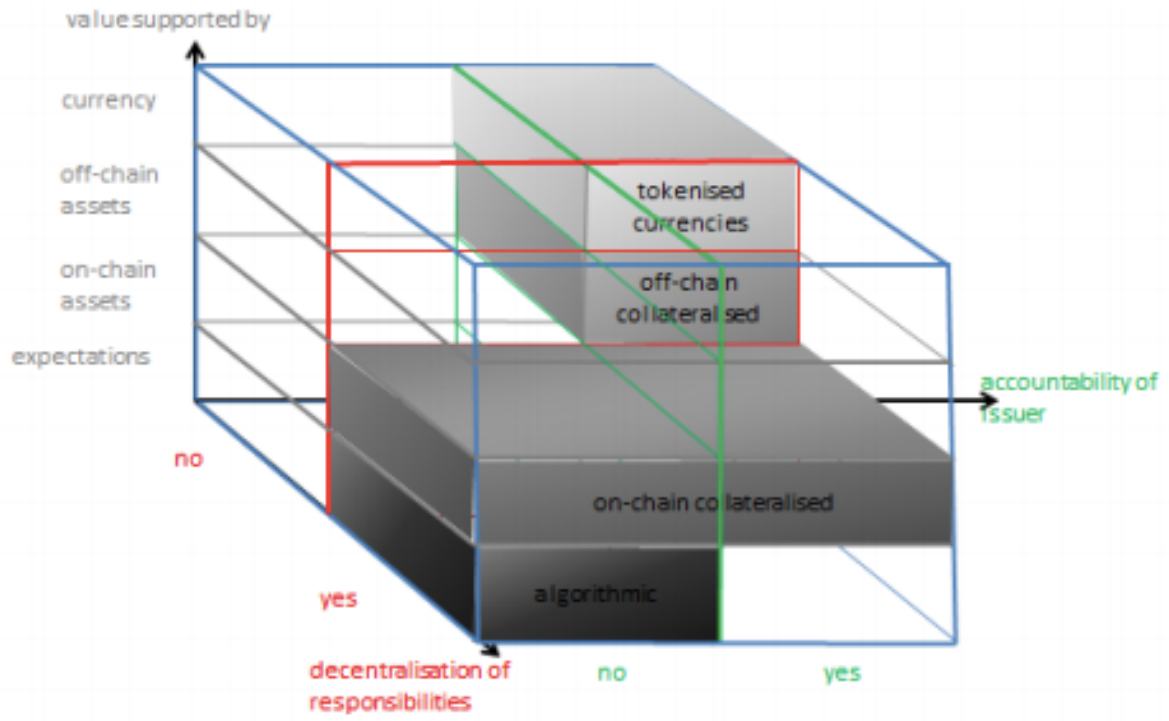

Figure 8 - crypto-cube (From ECB Occasional Paper Series No 230 / August 2019).

The "crypto cube" places emphasis on the specific stabilization mechanism they use to limit the volatility of their price in the currency of reference.

Stablecoins need to overcome three main hurdles to become widespread:

1. they must become legitimate in the eyes of governments and regulators. That means bringing stability to the price.
2. Create a robust financial system entirely on electricity consumption.

3. The financial system needs to be ready to overcome any kind of electricity shutdown or cyberattack. Governments may increasingly need to safely store back up of citizens data in an alternative country because cyberattacks are also becoming more frequent[29].

Anyway, the most valuable type of stablecoin is the uncollateralized one hence it creates cash flows that are independent of central bank control and, ultimately, of governments themselves. Of course, governments would still be needed, but only for the creation of infrastructure to support the huge changes in national currencies. The stablecoins could introduce a new level of confidence and trust, whereby people around the world would choose a global currency over their local regime. However, creating and maintaining stability in the current chaotic political and economic climate still seems out of reach. For this, it might be better to wait until the cryptocurrencies reach maturity and see how they interact with traditional instruments, before trying to create a stablecoin that change economy. In fact, UE stated that "*no global stablecoin project should be given the green light in Europe until legal, regulatory and supervisory challenges and risks have been adequately identified and addressed*". But something is seems to be changing exponentially during these end time.

For example, Facebook initiated project Libra with the main aim of enhancing financial access for underserved populations and providing faster and more efficient retail payments across borders. Libra will be backed by financial assets such as a basket of currencies and US Treasury securities in an attempt to avoid volatility. Unlike the cybercurrency bitcoin which use a permissionless blockchains, Libra will use a permissioned technology relying on trust in the independent Libra Association[30] as a de facto central bank.

This was a "wake-up call" for banks that are valuating to provide a digital form of their currency to the public, as they do with physical cash. In fact, one of the risks of cryptocurrencies is the unlawful usage, such as the vehicle for illegal transactions. This was one of several motivations for central authorities to introduce their own version of digital currency called Central Bank Digital Currencies (CBDC).

[29] In January 2018, the Tokyo-based cryptocurrency exchange Coincheck reported that hackers had taken £400m. Even though transactions for many cryptocurrencies are public, all 523m stolen coins ended up in nameless accounts.
[30] a membership organization.

Era of Central Bank Digital Currencies.

This chapter aims to give a complete framework of Central Bank Digital Currencies (CBDCs), starting from the definition, characteristics and design until explaining the many researches and projects application carried on by central banks around the world. To conclude, it will give a framework on how CBDCs could fulfill the role of money.

This "*disruptive innovation*"[31] (Clayton Christensen and Joseph Bower in 1995) has led to the emergence of digital currencies that represent both an innovation in payment system and a new form of currencies. Therefore, some central banks have started to consider whether they might issue their own digital currency. According to a survey conducted by the Bank for International Settlements in 2018, to which 63 central banks responded, 70% of them were then (or planned to be soon) engaged in central bank digital currency work. The common view seems to envision a central bank issued digital currency to replace or complement physical cash.
In fact, according to a second report by the International Monetary Fund (IMF) on June 27th of 2019, less than two weeks after Libra was officially announced, central banks may issue digital currencies in the future. However, actually the creation of Libra has stalled as the process of the launch seems to have been jammed up by regulators across several continents[32]. Still, though, the list of countries exploring the issuance of CBDCs is growing.

To understand why and how CBDC is attractive, this chapter will analyze different aspects and the possible consequences of the issuance of CBDC.

Definition

As our starting point, we state the definition: "*By CBDC, we refer to a central bank granting universal, electronic, 24x7, national currency-denominated and interest-bearing access to it balance sheet*" (Barrdear and Kumhof, 2016).

Another general definition was offered by Bank of England in 2018 as follow: "*Central bank digital currency is any electronic, fiat liability of a central bank that can be used to settle payments, or as a store of value. As such, CBDC can be viewed as electronic narrow money and in some senses already exists in the form of central reserves*". (Meaning et al.).

[31] "*Disruptive Techonologies: Catching the Wave*". It means a technology whose application significantly affects the way a market or industry functions.
[32] Facebook itself said earlier this year that the network might never launch.

According to other definitions, such a currency (central bank-issued) could also be named electronic base money (EBM), digital base money[33] (DBM) or e-money (Meaning et al. 2017).
That is to say, there is no single definition as the debate on both its denomination and design remains unsettled but it is important to not confuse with digital currency or virtual currency[34] because is the digital form of fiat money.

Anyway, as said before, we count as CBDC deposit liabilities that are electronically registered on the central bank balance sheet. Access to these deposits is universal[35] and the central bank issues these liabilities by crediting the accounts of money users. So CBDC, is *electronic, universally accessible, central bank issued money*.

This definition allows us to fit CBDC into the Venn diagram of the three existing forms of money, shown before.

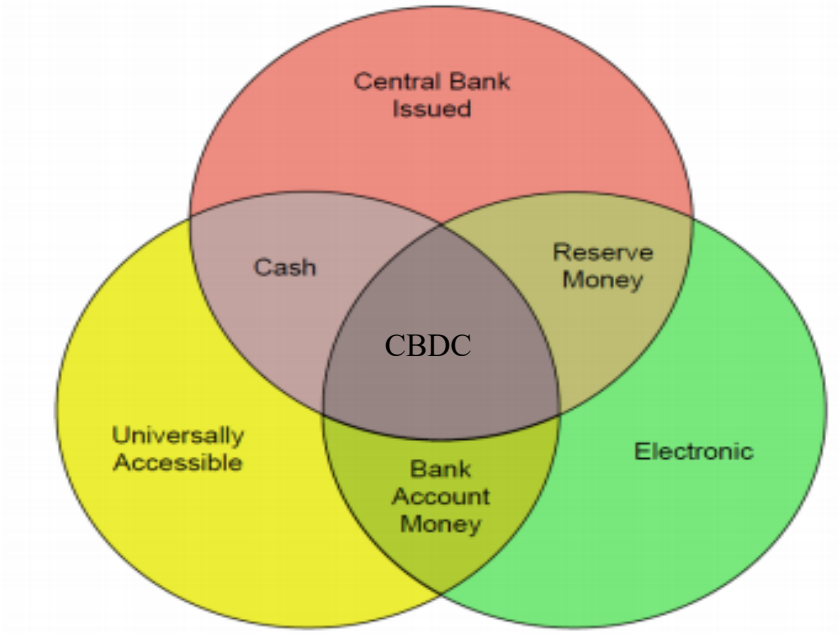

Figure 9- the features of CBDC (Source: Ole Bjerg, 2017)

As it shown, while each of the three existing forms of money is defined by lacking one of the features, CBDC is defined by no such lack. CBDC combines all the three features of cash, bank money and central bank reserve money. This has profound implication because it means that CBDC potentially competes with all of the existing forms of money. In fact, CBDC could be considered a third form of base money, next to overnight

[33] European Central Bank (Retrieved November 9, 2017).
[34] Virtual currency and cryptocurrency are not issued by the state and lack the legal tender status declared by the government. (Silva, Matthew De. 2019)
[35] Which means that they can be held and used by principally all money users in the economy.

deposits, currently available only to banks and specific non-bank financial firms, and some official sector depositors and banknotes, being universally accessible.

Design

The most important design choices are related to access, anonymity, availability and interest-bearing characteristics. The CBDC's design features depend on the objectives and motivations of the central bank. Currencies can either be token-based or account-based. If token-based, careful thought should be given to the appropriate degree of anonymity. As with all currencies, CBDC would also require an infrastructure to support its distribution (centralized or decentralized). As a digital currency, CBDC must also have a place a validation scheme (centralized or decentralized) to prevent double spending or identity theft. Finally, digital currencies can be subject to caps and /or accrue interest (BIS Committee on Payments and Market Infrastructures, March 2018). [36]

Tokens vs. Accounts

As explained above, the blockchain can remove the need for transaction intermediaries and, rather than requiring users to have trust in special institutions that hold the record and are trusted to ensure its validity[37], the ledger containing the record of all transactions by all users is publicly available to all (Bank of England Quarterly Bulletin, 2014). The technology itself establish the trust and create a pure, digital record that cannot be tampered or exploited and, last but not least, is independent of any institution.

Anyway, the technological vehicle for the CBDC could be token-based, involving the transfer of an object of value from one wallet into another, or account-based, involving the transfer of a claim recorded on one account to another (Tommaso Mancini-Griffoli, IMF Staff Discussion, 2018)[38].

The distinction between tokens and accounts is in the method of verifying an exchange: the focus of verification for token-based money is the object transferred and the focus of verification for account-based money is the identities of the account holders (Harvard Law School, The Case Studies "Cryptocurrencies").

CBDC tokens would use some form of distributed ledger technology for verifying the chain of ownership of each token and validating payment transactions, without requiring the direct involvement of the central bank or any other clearinghouse. However, the central bank would determine the supply of CBDC tokens, which would be fixed in nominal terms and serve as legal tender. This is often associated with anonymity, i.e.

[36] See the BIS report by Committee on Payments and Market Infrastructures, March 2018.
[37] As it happens with conventional bank deposits.
[38] Cash and Bitcoin are examples of token-based money, whereas bank accounts and debit cards are examples of account-based money.

meaning that the central bank would not know who currently holds the issued tokens but only the object transferred[39].

Under the alternative design, individuals and firms would hold funds electronically in CBDC accounts at the central bank or in specially designated accounts at supervised depository institutions. Under this approach, the central bank would process each payment transaction by simply debiting the payer's CBDC account and crediting the payee's CBDC account. The most important advantage in CBDC payments on account-based system is the quickness but, during the initial creation of each CBDC account, the identity of the account holder would need to be verified. After that, payment transactions could be conducted rapidly and securely[40] and central bank would be able to monitor any unusual activity and implement additional anti-fraud safeguard as needed (Bordo and Levin, 2017). However, if CBDC could be offered in the form of deposit accounts with the central bank to all households and corporates, from a technological perspective, this would not be very innovative, but just a matter of scaling the number of deposit accounts currently offered.[41] The maintenance of the accounts could be assigned to one or several third-party providers to ensure efficiency and to avoid that the public sector takes over more task than needed. While commercial banks would provide the service to exchange bank deposits against CBDC and banknotes, charging a competitive fee[42].

To conclude, it is shown below a graph to summarize the main differences in technological mechanisms.

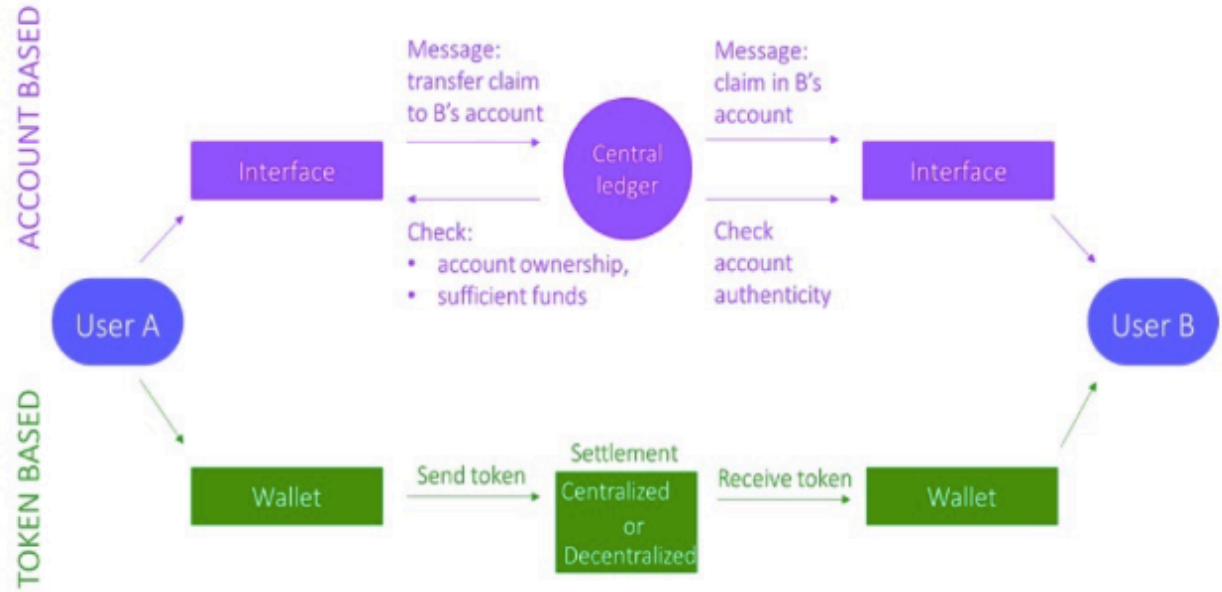

Figure 10- Account and Token-Based CBDC, Basic Mechanism (Source: IMF Staff)

[39] A straightforward example is a token that represents equity in an organization built on a blockchain platform where "the token-holder receives future cash flows from a successful project" (Hu, Parlour and Rajan 2018). Another example is Nexo, which is a crypto loan company that pays out a portion of the profits to Nexo token holders.

[40] For example, using two-step verification with a cellphone and digital pn

[41] In the case of the Eurosystem, the number of accounts could grow from around 10,000 to some number between 300 and 500 million, calculated considering all registered major inhabitants of the euro area, plus firm fulfilling some legal status and/or some minimum criteria on payment or economic activity. (ECB, Tiered CBDC and financial system, Jan 2020)

[42] Similarly to ATM feed today.

Access

The accessibility is opened to retail customers, both individual and firms, and to financial intermediaries, in particular commercial banks. There is a distinction between a wholesale CBDC (WCBDC) and a retail CBDC (RCBDC). A WCBDC would be accessible only to financial intermediaries, while a RCBDC would be accessible to the general public, including financial intermediaries.

In 2018 the Committee on Payments and Market Infrastructures (CPMI) and the Markets Committee (MC) provide a taxonomy of money ("*The money flower*") which delineated between two broad types of CBDC.

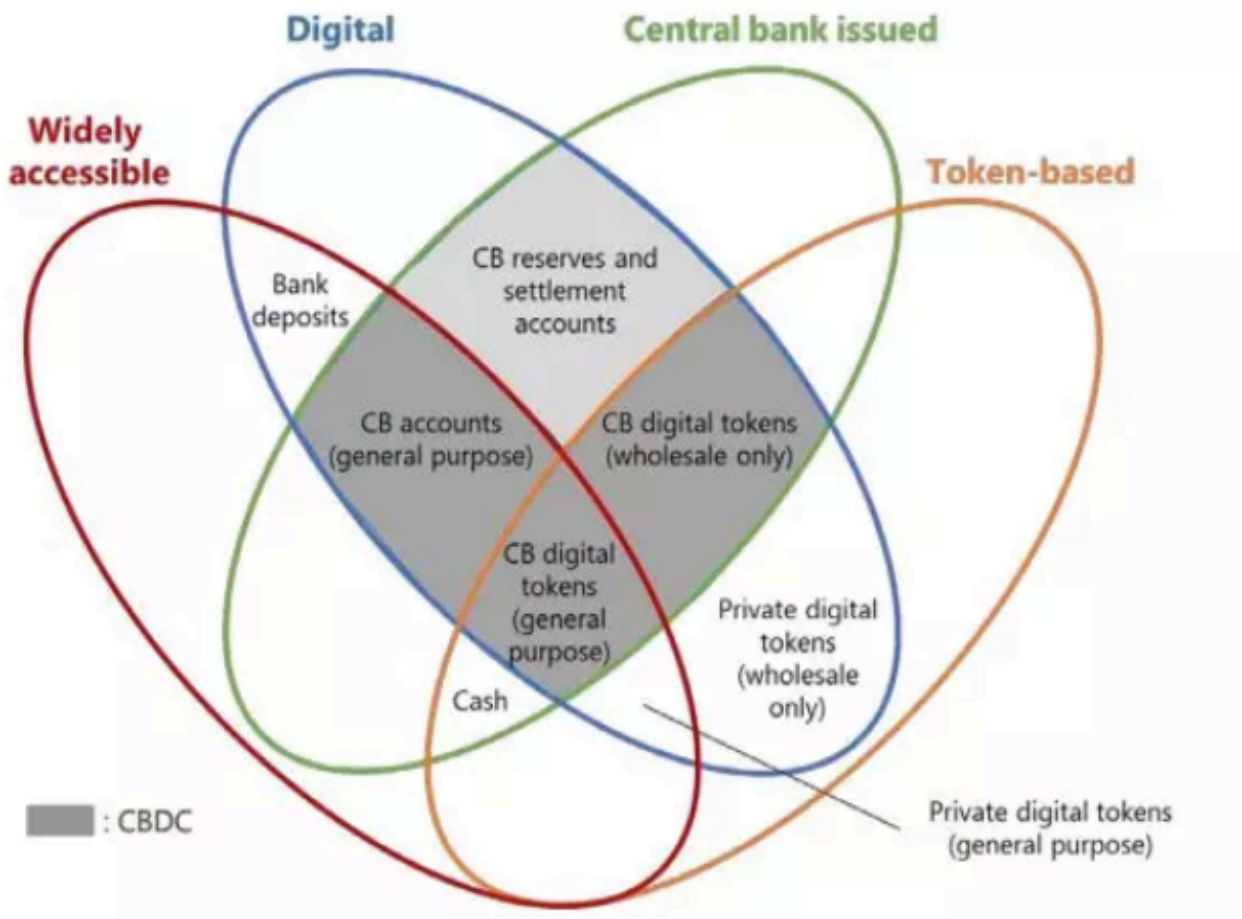

Figure 11- The money flower (Sources: CPMI-MC (2018); Bech and Garratt (2017)).

This Venn diagram illustrated the four key properties of money:

- issuer (central bank or not);
- form (digital or physical);
- accessibility (widely or restricted)
- technology (account-based or token-based)

In sum, the report identified three variants of CBDC highlighted by the deep-grey-shaded areas.
The first is a "general purpose" (RCBDC) in two variants: account-based and token-based. The first one is an account at central bank for the general public, widely available and primarily targeted at retail transactions and also for broader use.
The second one is a digital cash issued by the central bank for general public. The main difference between the variants is in the way would be distributed and transferred.
The main concept of retail CBDC is widening access of central bank's money to the all economic agents so this mean that the central bank's balance sheet can be accessed not only by the commercial banks but also by other financial institutions, the governments and even households and non-financial institutions.

The last form is a wholesale token-based variant (WCBDC) and the access is restricted for wholesale settlements (e.g. interbank payments or securities settlement). It can be similar with current's central bank reserves where only the commercial banks are allowed to have direct accounts in the central bank but, in this option, not only the commercial banks but also other financial institutions and wholesale money market participants can access the central bank's balance sheet.

In the money flower graph, the "CB reserves and settlement accounts" are highlighted in light-grey because the commercial bank deposits of consumers and businesses are stored in electronic form[43]. Furthermore, central banks' deposits can concretely be referred to as a form of central bank digital currency although they are neither a cryptocurrency, because they are not distributed through an encrypted DLT network infrastructure, nor they don't have universal accessibility[44].
Anyway, access is non-exclusive and anyone could use the CBDC but it's required the related technology.

Transfer mechanism

The currency will be held and transferred with a chip card or a digital wallet[45] available to any person or firm with the technology, through various devices, including personal computers, tablets and mobile phones with online capability. Actually, the transfer of cash is conducted on a per-to-peer basis while central bank deposits are transferred through the central bank, which acts as an intermediary. CBDC may be transferred either on a peer-to-peer basis, through token system, or with an intermediary that could be the central bank, commercial bank or a third parties agents using an account system.

[43]which means they are no physic but they represent a liability of the bank itself and transactions are still cleared across the books.
[44] A normal citizen can't have a deposit account at the central bank, as opposed to traditional commercial banks.
[45] The digital wallet would be provided by designated private service providers that are certified or licensed by the central banks.

Anonymity

Currently, central bank money available to retail users (i.e. cash) is completely anonymous, while that available to financial intermediaries (i.e. reserves) is note.

As seen before, token-based systems rely on verifying the authenticity of the exchanged token, not the identities of the transacting parties[46] so the payer "*need reveal nothing to the payee beyond the information associated with the specific coin*" (Kahn, Rivadeneyra and Wong 2018). As such, CBDC can be designed to provide different degrees of anonymity for its users or traceability for its transactions.

In fact, the blockchain does not record real names or physical address but the transactions of the ledger are public and would be traceable to the owner of the wallet. Instead, cash transactions are completely anonymous to third parties like banks and government and this feature is an attractive quality for users to protect the privacy of their transaction histories.

So, the degree of anonymity of CBDC will be depending on the technology used.

If it will be used an account-based system, generally it requires some knowledge of the transacting parties' identities and there is a relative counterparty anonymity[47] and third-party anonymity is absent: banks would be "*required to have information regarding the individuals identities for a variety of legal reasons*" (Kahn, Rivadenyra and Wong[48], 2018). It is important to underpin that this means that all the economic agents that want to access CBDC should have direct accounts in the central bank. This would be account-based and central bank would be able to control the payment systems and this affecting all the transactions done in the economy. At the end, account-based CBDC could reduce the usage of money for illicit activities, such as terrorism financing, tax evasion and tax fraud even though there are some privacy issue that needs to be addressed.

Interest-bearing

As with other forms of digital central bank liabilities, it is technically feasible to pay interest (positive or negative) on both token and account based CBDCs. The interest rate on CBDC can be set equal to an existing policy rate or be set at a different level to either encourage or discourage demand for CBDCs. Moreover, rates could be differentiated on risk characteristics of counterparty.

Depending on the type of payment transaction, in this case retail, CBDC could be designed to be interest-free so non-interest bearing, just like cash.

Regarding this topic, the research department of the International Monetary Fund (Itai Agur Anil Ari Giovanni Dell'Ariccia) studied the optimal design of a central bank digital currency analyzing the impact on the welfare environment if CBDC would be interest-bearing like deposits or not. In fact, a CBDC could compete with

[46] How actually Bitcoin system works.
[47] For example, the parties only know the other's account number.
[48] "*Should the central bank issued e-money?"*

deposits and may lead to a decrease of bank credit or if it will be similar to cash may lead to the disappearance of cash.

The model assume that banks collect deposits, extend credit to firms and create social value in doing so. Households have heterogeneous preferences over anonymity and security in payments: cash provides anonymity in transactions while bank deposits are more secure.

Because of heterogeneity in household preferences, variety of payment instruments increases welfare.

CBDC will have a relevant social value due to its ability to unite the characteristics of cash and deposits but it has also welfare cost to the decrease in demand of these two. A cash-like CBDC will reduce cash demand but a deposit-like CBDC design causes an increase in deposit and loan rates and a contraction in bank lending to firms.

When the CBDC is not interest-bearing, the network suffers the less variety of systems of payment and it brings distortions in the households' choice of payment instruments. Indeed, when households care enough about payment instrument variety, the interest-bearing CBDC will optimally always keep cash alive, but it has impact on bank intermediation because it competes with deposits for their characteristic of traceability and protection from loss and theft.

So, in order to achieve the optimal design it is important to consider tradeoffs between network effects and financial frictions. Most central banks appear to be constraining themselves to non-interest-bearing due to political economy considerations. Alternatively, the need to tax positive interest earnings may interfere with a desire to offer a degree of anonymity on the CBDC in certain jurisdictions.

At the end the main result was that introducing an optimally designed CBDC always raises aggregate welfare, but far from Pareto improvement: some households gain while others lose. Central bank considers primarily non-interest-bearing CBDC to preserve banks intermediation. On the other hand, this is a distortionary instrument to affect household payment choice. However, it could be possible to arrive at optimally CBDC rate to safeguard bank intermediation and payment instruments variety.

The figure n°12 shows the aggregate welfare impact ($\Delta U = \Delta\pi + \Delta r_d$)[49] of introducing a CBDC across the distribution of household preferences of payment $i \in [0,1]$, where higher value of i denote a grater preference for anonymity and a lesser degree of security and vice versa. $\theta \in [0,1]$ is the optimal rate that a CBDC must have to maximize the users' welfare and it is determined by central banks. T is a lump-sum tax used to fund CBDC.

[49] Where $\Delta\pi$ is the profit that the firms could have from an increase of consumption due to a decrease of interest rate and r_d is the deposit rate.

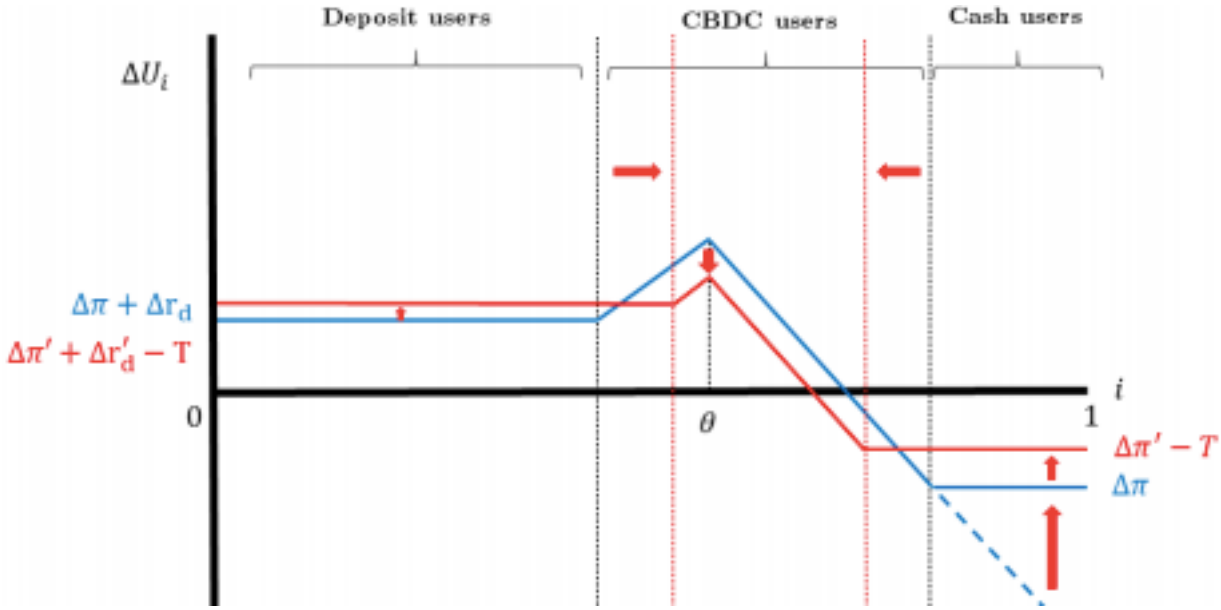

Figure 12-Distributional effects of CBDC (Source: IMF Staff)

The blue line depicts the impact of a non interest-bearing CBDC on the utility users' function.

The main consequences of a CBDC with design like cash, it is an inevitable increase in rate of deposit rate.

As you can see, households with preferences of safe payments (low i) remain as deposit users after the introduction of CBDC but they will have benefits from positive effects on bank deposits. On the one hand, the increase in deposit rate reduces total production and therefore profit transfers π from firms. On the other hand, CBDC competition with bank deposits drives up deposit rates r_d. Overall, the latter effect that dominates is the raise of the consumption and hence the welfare of all deposit users.

Instead, households with a strong preference for anonymity (high i) remain as cash users and the welfare will be impacted through consumption. Since cash does not pay interest, the decline in firm profit π brings a decline in consumptions and welfare for these households. If instead CBDC drives out the use of cash, these households suffer due to the loss of their preferred payment instruments. Moreover, the extent of their welfare loss then becomes proportionate to their preference for anonymity.

Households that switch from deposits to CBDC will have a net welfare gain from CBDC introduction. These users will switch to CBDC only if the gain in term of payment preferences outweighs the loss of interest payment r_d. The households with $i = \theta$ would have the greatest increase in welfare instead for these marginally prefer CBDC over cash, the net welfare effect is negative, since CBDC holders also suffer from a fall in consumption due to reduced firm profits.

At the end, depositors have the main advantage and cash holders emerge as the main losers.

Instead, the red line shows the welfare impact of an interest-bearing CBDC[50].

[50] The rate is slightly negative.

Three factors determine the impact of negative CBDC:

- The revenues from negative CBDC rates are transferred lump-sum to all households, which effectively redistribute welfare gain from CBDC users to cash and deposit users.
- Negative CBDC rates increase deposits and financial intermediation, firm profits π rise, which benefits all households while deposit rate r_d decreases. However, this second effect of negative CBDC is dominated by the first, in that all CBDC users lose out and deposit and cash users gain from the CBDC rate cut.
- Finally, CBDC rates prevent the disappear of cash and large loss of welfare for cash holders due to the loss of their preferred payment instrument.

To conclude, the optimal CBDC rate diverges from zero and it is slightly negative. When there is no CBDCs, deposits and cash are able to coexist, as they do in most countries[51] but, as you can note, an optimally design CBDC rate always raises welfare.

Limits or caps

To control undesirable implications or to steer usage in a certain direction, different forms of quantitative limits or caps on the use or holdings of CBDC are often mentioned (Committee on Payments and Market Infrastructure, BIS 2018). Limits or caps could make a CBDC less useful for wholesale rather than retail payments. The proper functioning of the payment system implies one-to-one convertibility of CBDC with respect to reserves and banknotes (Fung and Halaburda 2016) in order to do not break the unit of the currency. However, some have proposed allowing to break this unit under certain circumstances. For example, Agarwal and Kimball (2015) propose "*abandoning one-to-one convertibility as a way of allowing a floating exchange rate between cash and commercial bank deposits and thus eliminating the effective lower bond*". Abandoning convertibility between CBDC and reserves would similarly lead to a floating exchange rate between CBDC and commercial bank deposits. So, at present, such limits or caps on holding/use are most easily envisioned in non-anonymous account-based systems.

[51] In Canada, cash is widely accepted although only about 10 percent of transactions in value terms are conducted with cash. In contrast, in Sweden, where network effects on cash are becoming a source of concern, cash use sands near 1 percent of transaction value.

Effects

The CBDC survey amongst 63 central banks[52] of Barontini and Holden (2018) reports that for central banks the four most popular reasons to consider CBDC are, in order of importance:

1. Payment safety;
2. Payment efficiency;
3. Financial stability;
4. Financial inclusion.

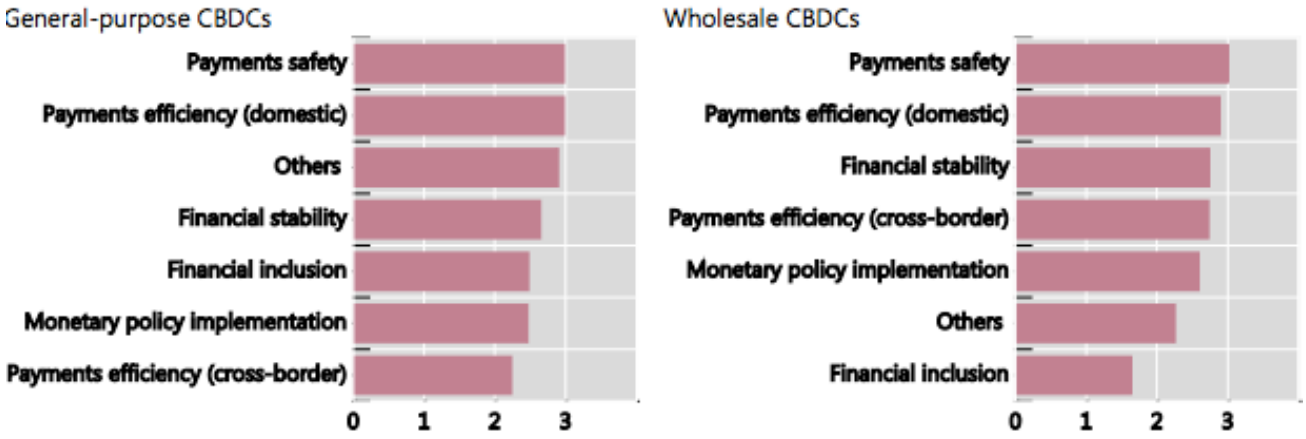

Figure 13 – Motivation for issuing a CBDC, ranked in order of importance. The score is calculated as an average of the options:
"Not so important" (1), "Somewhat important" (2), "Important" (3) and "Very important" (4).
(Source: Central bank survey on CBDCs)

So, there are several benefits of CBDC that have been put forward but there are some conditions to satisfy in order to achieve these advantages.

Efficient payments

The currency offers a number of advantages with regards to convenience, efficiency, stability and accessibility of payment.

For what concerns retail, while electronic payments with all their efficiency gains have been possible for some decades on the basis of commercial bank money, offering electronic payments directly in central bank money

[52] 63 central banks participated in the survey: - Argentina - Australia - Azerbaijan - Bangladesh - Belgium - Brazil - Cambodia - Canada - Cape Verde - Cayman Islands - China - Colombia - Curaçao & Sint Maarten - Cyprus - Dominican Republic - Ecuador - Egypt - Euro area (ECB) - France - Georgia - Germany - Hong Kong SAR - Hungary - India - Indonesia - Iraq - Israel - Italy - Jamaica - Japan - Jordan - Kazakhstan - Korea - Kosovo - Latvia - Malaysia - Montenegro - Morocco - Netherlands - Nigeria - Norway - Pakistan - Papua New Guinea - Philippines - Russia - Samoa - Saudi Arabia - Serbia - Singapore - Slovenia - Solomon Islands - South Africa - Spain - Sweden - Switzerland - Thailand - Tonga - Turkey - United Kingdom - United States - Uruguay - Vietnam - Zambia

could have additional advantages[53]. The demand for cash will collapse because CBDC would have lower user costs than cash, which could prompt substitution from cash to CBDC for retail and peer-to-peer person. Moreover, CBDC would facilitate online transactions that are currently foregone because of friction that inhibit some types of transactions[54]. At the end, it could lead to a reduction of transaction costs for retail and institutional payment. On the other side, trust in the currency would entirely depend on trust in financial intermediaries issuing and managing commercial money.

In a same way, CBDC reduces working capital required for cross-border transaction service, decreasing time to dispute resolution and reconciliation and make speedy and simultaneously clearing and real-time settlement processing.

To sum, have a secure and standard instrument of payment backed by a central bank enhance confidence in money system and increase resilience in national payment system.

Financial inclusion

Financial inclusion could improve access to digital payments for unbanked household. Some consumers that actually today do not have a bank account, could have access to these tools at minimal or zero cost with CBDC. It is important to underpin that bank accounts have an important part to play in the founding and expanding of business, making transactions more efficient, secure and transparent and managing savings, especially in emerging economies.

The Global Findex database states that 1.7 billion of adults in the world remain unbanked in 2017, neither with an account at financial institution or through a mobile money provider. While in high-income economies it is normal and universal have a bank account, all these unbanked adults live in the developing world.

Indeed, nearly half of them live in seven developing economies: Bangladesh, China, India, Indonesia, Mexico, Nigeria and Pakistan.

The unbanked are likely to come from a poorer environment. In economies where only about 20-30% of adults are unbanked, however, the unbanked are much more likely to be poor and have low educational background. To shed light on why people are unbanked, the 2017 Global Findex survey asked adults without a financial institution account why they do not have one. The most common reason was having too little money to use an account. Cost and distance were each cited by about a quarter of those responding to the question, and a similar share said they do not have an account because a family member already has one. Lack of documentations and distrust in the financial system were both cited by roughly a fifth of adults without a financial institution account, and religious concerns by 6 percent.

[53] A comprehensive analysis of these justifications of CBDC can be found for example in Sveriges Riksbank's second report on the e-krona project (Swedish CBDC).

[54] For example, some consumers avoid online purchases because of security and privacy concerns when providing their credit card information. Also, smaller merchants often avoid selling online because of card fees, especially for small-value transaction.

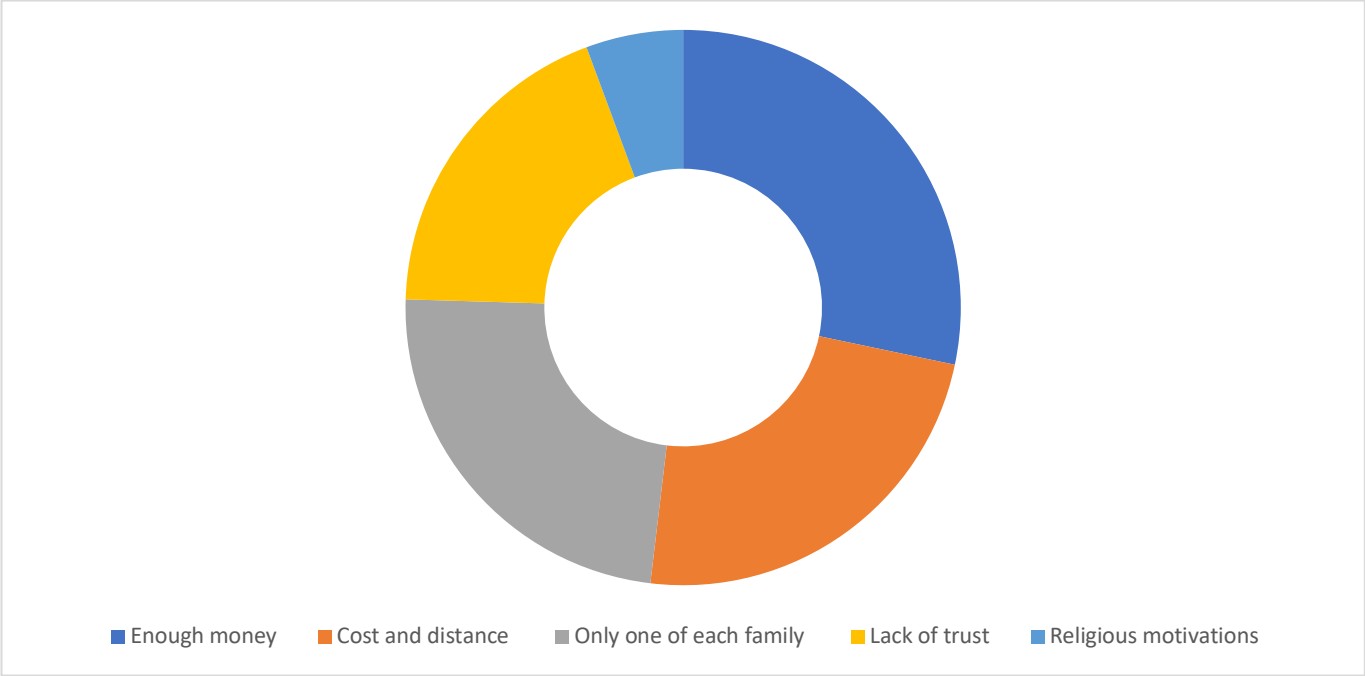

Figure 14- Reasons to remain unbanked (Sources World Bank)

Adolfatto model

David Andolfatto in his paper "Assessing the Impact of Central Bank Digital Currency on Private Banks" (2018) has investigated the impact of CBDC on the banking sector. The model demonstrates that CBDC enhances financial inclusion, increasing the number of bank accounts in the economy. This will be useful especially in countries where banking sector penetration is low. The second main finding is that CBDC has no effect on banks' lending activity but it reduces banking monopoly profits.

The theoretical model adds the Diamond (1965) model of government debt at the Klein (1971) and Monti (1972) model of monopoly bank.

The assumptions of the model are that the banking sector is not perfectly competitive, both bank deposits and CBDC use the same real-time payment system and young workers have linear preferences. Furthermore, the interest paid on CBDC is different than interest paid on reserves.

In the model there are in each period t four individuals: old workers, old firms, young workers and young firms.

The young workers have heterogeneous levels of working skill and linear preference, so they will choose to save their income and maximize their wealth at $t + 1$. While old workers will consume in t the income that they earned in $t - 1$. The young firms have an investment project and the units of product k_t are invested at t yields. Below, the definite sequence.

Timing

Old workers enter in period t with the money (cash or deposit) they worked for and saved in the previous period. They receive money transfer Z_t, in form of deposit for these with bank account and in form of a check for the unbanked.

Old workers spend all their money on goods and services. Old firms enter in t with bank debt which they repay (interest and principal) at the end of the period. Firms use their physical capital (the previous period's investment) to produce goods and services, a part of which they consume (profits) and the remainder which they sell for money. The money they acquire from sales is used to repay bank loans and pay taxes (T).

Young firms enter in t with an investment project that needs financial resources. Banks provide it at interest rate R_t^L. Firms pay ϕ and open an account bank. Then they pay cash workers without bank deposit and workers with bank account are paid by deposit transfer.

Young workers enter in t and choose whether to access the banking system or not.

Private banks set the deposit rate R_t^D and central bank sets CBDC deposit rate R_t^M. Unbanked receive cash for their product and banked workers get paid directly by deposit and earn either the deposit rate R_t^D or R_t^M, depending on whether they hold their money in private or central bank accounts.

Government policy

The government make monetary transfers Z_t, collects tax revenues T_t but does not make purchases ($G_t = 0$). The deficit is completely financed with one period, risk free nominal money/debt, represented as follow:

$$D_t = C_t + M_t + B_t$$

where C_t is the physical cash in circulation in economy, M_t the interest bearing of CBDC and B_t interest on reserves debt commercial bank holds at central bank.

Assume that tax revenue gained from taxes paid by firms is exclusively used to fund interest expenses

$$T_t = (R_{t-1}^B - 1)B_{t-1} + (R_{t-1}^M - 1)M_{t-1}$$

and monetary transfers are financed by new debt issuance $Z_t = D_t - D_{t-1}$

where R_t^B is the gross nominal interest rate on bond and R_t^M is gross nominal interest rate on CBDC.

In this model, the digital interest-bearing part of government debt is held by financial intermediaries. Private bank and central bank transform illiquid securities into liquid payment system[55]. Workers want to accumulate securities in exchange for labor and will accept either private bank or central bank securities as payment (CBDC or commercial bank deposits).

[55] Central bank transforms illiquid government debt into reserves for private banks and CBDC for workers and firms.

Individuals have to pay ϕ, a fixed cost to pay only one time in order to set up the bank account that takes form of "utility cost" in terms of spent time. And they can save money at commercial bank's deposit rate R_t^D or at CBDC deposit rate R_t^M and borrow money at R_t^L.

Unbanked people must resort cash and they will spend a portion of their income $(1-\theta)y$ to manage the cash from one period to the next. This discourages people to have large amounts of cash at zero nominal rate.

Decision Making

The young firms choose to borrow k_t from banks at lending rate R_t^L to maximize future wealth profit, in this way.

$$w_{t+1} = F(k_t) - R_t^L \Pi_{t+1}^{-1} k_t - T_{t+1}$$

k_t is the investment demand and is adjusted for inflaction and lending rates.

Compute the first derivative of k_t to maximize: $F'(k_t) = R_t^L \Pi_{t+1}^{-1}$

The value of the created bank loan is credited to young firms directly through their bank accounts, however firms do not keep any of this money until the next period $t+1$ but they use to pay workers and to complete investment project.

For the workers without a bank account the payoff will be:

$$w_{t+1}^u = \Pi_{t+1}^{-1} \theta y + z_{t+1}$$

where $\Pi_{t+1}^{-1}\theta y$ is the rate of return of cash net of cost of carrying cash.

The workers with an account will choose between the two form of deposits according to which has the higher interest rate. $R_t = max\{R_t^M;\ R_t^D\}$

The payoff of banked young workers is given by:

$$w_{t+1}^b = \Pi_{t+1}^{-1}[R_t y - \theta] + z_{t+1}$$

By equating the payoff we find a level of income Y that makes workers indifferent between having a bank account or not.

$$\widehat{y(R_t)} = \frac{\phi}{R_t - \theta}$$

All workers with $y > \hat{y}$ will access to banking system and all workers with $y < \hat{y}$ will remain unbanked.

As you can note, higher ϕ will disincentive workers to have bank account while higher R_t will incentivize and a smaller θ promotes the use of cash.

The inflation rate does not affect the decision to access the banking system or not because the rate of return of cash and deposit money are both affected in the same way by the rate of inflation.

The aggregate demand for real cash balances in this economy, or cash in circulation, is given by:

$$c(R_t) = \int_0^{\widehat{y(R_t)}} y dG(y)$$

The demand for real cash balances $c(R_t)$ is decreasing in the nominal deposit rate R_t and is independent of the inflaction rate. If the expectation of inflation increases, the rate will be lower and this affect the aggregate demand because lower rate incentives worker to use cash and save money.

If $G(\widehat{y})$ is the fraction of young workers that choose to use cash, 1- $G(\widehat{y})$ will choose to use deposit money. So, the aggregate demand for real deposit balance is:

$$q(R_t) = \int_{R_t}^{\infty} ydG(y)$$

The demand for real deposit balance $q(R_t)$ is increasing in the nominal deposit rate R_t and is independent of inflaction rate.

The aggregate supply of real savings in this economy is:

$$y = \int_{0}^{\infty} ydG(y)$$

From the preceding demand we have this supply:

$$y = c(R_t) + q(R_t)$$

So, the nominal interest rate here simply determines the composition of real money balances between cash and deposits and not the total supply of savings. Whether deposits are held as bank deposits or CBDC depends only on the relative R_t^D and R_t^M.

Now, let us consider the behavior of banking sector under the effects of introduce CBDC.

At t, banks possess reserves B_t and loans $p_t k_t$. It finances its asset portfolio entirely with deposit liabilities $p_t q_t$, so its balance sheet is: $B_t + p_t k_t = p_t q_t$

This balance sheet generates an expected profit: $V_{t+1} = R_t^B B_t + R_t^L p_t k_t - R_t^D p_t q_t$

Combining the two precedent, banks will choose R_t^D and R_t^L to maximize the profit, as following:

$$V_{t+1} = (R_t^L - R_t^B) p_t k_t (R_t^L \Pi_{t+1}^{-1}) + (R_t^B - R_t^D) p_t q_t (R_t^D)$$

where $q_t(R_t^D) = \begin{cases} q_t(R_t^D) \; if \; R_t^D > R_t^M \\ 0 \; if \; R_t^D < R_t^M \end{cases}$

So, if the deposit rate offered by banks exceeds the deposit rate offered by CBDC, then workers will hold all of their deposits with banks and vice versa.

The bank is assumed to choose a lending rate R_t^L and a deposit rate R_t^D to maximize its value V_{t+1} taking as given the police rate R_t^M and R_t^B and the behavior of depositors.

The conclusion of this model is:

- When $R_t^D > R_t^M$ an increase in R_t^D reduce the bank's profit but increase deposit demand, and banks will have more accounts which gain the profit margin $(R_t^B - R_t^D)$
- An increase in R_t^L would increase profit by $k(R_t^L)$ but decrease demand for loans and which banks earn profits $(R_t^L - R_t^B)$
- $R_t^L = (\frac{1}{a})\ R_t^B$ so IOR (interest on reserves) is set independently of R_t^M, only if $R_t^M > R_t^B$.

Findings

The main findings are that CBDC has no effect on banks' lending activity, but it reduces banking monopoly profits that depend only on opportunity cost of bank lending (IOR). Actually, individuals held deposits at commercial banks which then lent to central bank and to individuals. After issuing CBDC, individuals hold deposit at central bank if $R_t^M > R_t^B$ which lends money to commercial banks at rate R_t^B. So CBDC make banks more competitive. It could be a striking conclusion that CBDC need not have impact on bank lending operations and banks are not disintermediated.

Finally, until $R_t^B > R_t^M$ commercial banks will offer a deposit rate R_t^D marginally higher than CBDC R_t^M. More unbanked individuals will be willing to pay ϕ to get a bank account and earn R_t^M. So in this way, financial inclusion is likely to increase. In fact, if CBDC is available, it provides access to a perfectly safe deposit account and acts as a competitor for bank deposits at commercial banks. This can let banks to improve their services by offering cheaper and/or better products but, on the other hand, may lead banks to invest in and give loan to riskier projects at higher rate, resulting in a less stable financial system. We now go deeper into this issue.

Financial Stability

Dyson and Hodgson (2016) consider that CBDC "*can make the financial system safer: allowing individuals, private sector, companies and non-bank financial institutions to settle directly in central bank money (rather than bank deposits) significantly reduces the concentration of liquidity and credit risk in payment systems. This in turn reduces the systemic importance of large banks and thereby reduces the negative externalities that the financial instability of banks has on society. In addition, by providing a genuinely risk-free alternative to bank deposits, a shift from bank deposits to digital cash reduces the need for government guarantees on deposits, eliminating a source of moral hazard from the financial system*".

The possibility of having an account with the central bank can determine more direct transmission for monetary policy, without the current role played by the financial system in addition making the implementation of monetary policy more transparent.

So, the introduction of CBDC could affect financial stability and banking intermediation if it competes with bank deposits. For his traceability and protection from loss or theft nature, it is reasonable to assume that

someone will prefer and adopt CBDC. In this case banks could increase deposit interest rates or providing more complementary financial services to make them more attractive.

Higher interest rates reduce banks' interest margin and banks would attempt to increase lending rates, though at the cost of loan demand[56].

As you can see from figure n°15 below, the introduction of CBDC leads to a reduction of quantity of deposit from D_1^* to D_2^*.

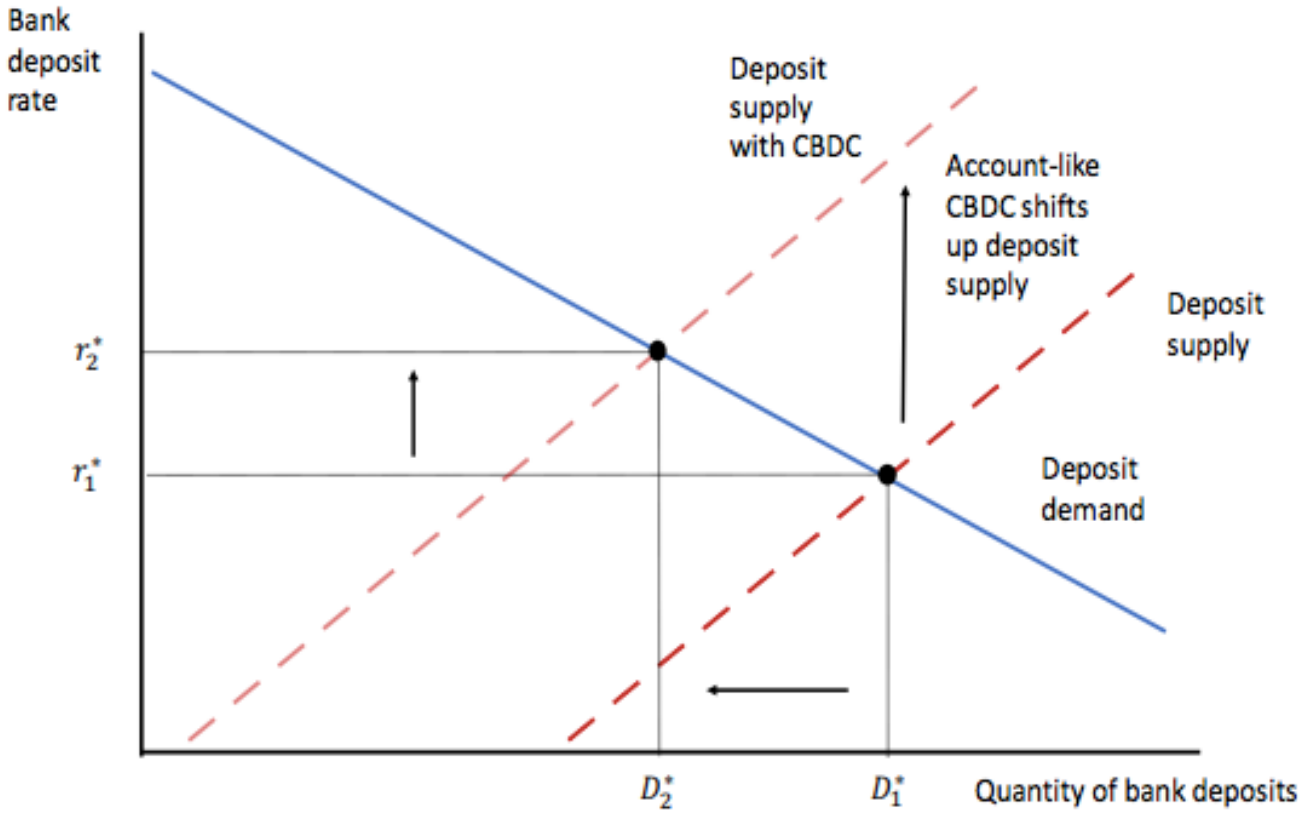

Figure 15 – Introduction CBDC (Source: IMF Staff)

Banks will react increasing the interest rate on deposits. From graph n° 16 you can see that if banks have more market power in lending, they will protect better their profits by passing the deposit rate hike on to loan rates. Moreover, banks with little market power adjust more quantity, leading to a larger contraction in deposit and loan volume.

[56] The net impact of CBDC depend also oh how the central banks introduce it, because if there will be an injection of CBDC via the sale of government bonds, this could lead to lower rates (Barrdear and Kumhof 2016).

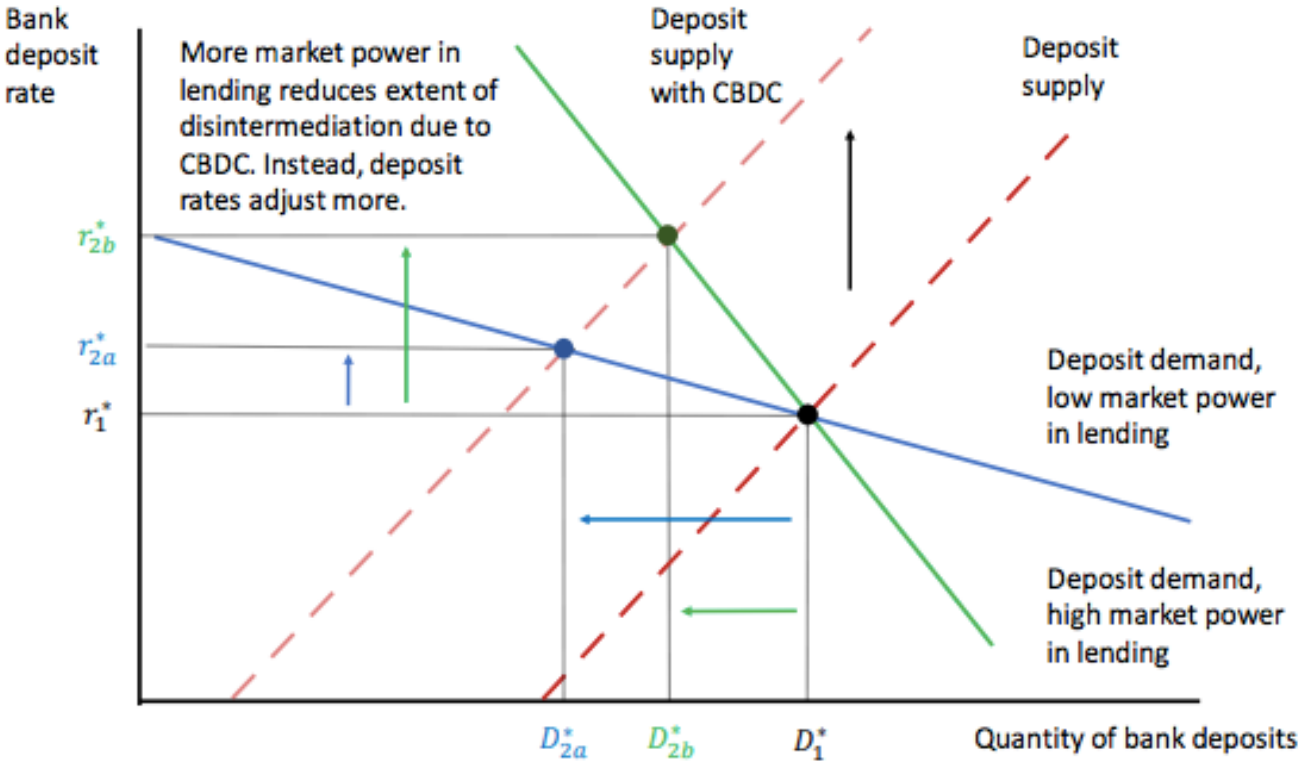

Figure 16- Effects of CBDC and market power in lending (Source: IMF Staff)

The main consequences of introduction of CBDC are three:

1. Bank funding would become more expensive, due to higher interest rate.
2. Market discipline affect in the banking sector: losing traditional depositors banks could be more attractive to take on more risks.
3. Bank funding may become less stable: if retail depositors prefer CBDC to wholesale depositors, bank funding could become more volatile and banks will have to hold more liquid assets to meet regulatory requirements.

The equilibrium could be that central bank limits the decline in bank deposits by setting limits on individual CBDC holdings or discouraging convertibility from bank deposits to CBDC or, still, allowing banks to manage CBDC because there are many pros that can lead to develop public trust and mitigate systemic risk.

First at all, central banks facilitating instant settlement on their ledgers, the systemic risk involved in transactions decreases by reduced collateral and the probability of default in agreed-upon transactions. Moreover, CBDC can recapture a portion of seigniorage[57] if physical cash declines. Due to low interest rate, seigniorage has fallen since 2008 and if public opts to a private-cryptocurrencies, central banks seigniorage revenues could decrease further. But commercial banks can earn some revenue when they issue bank deposits as direct consequence of financial inclusion.

[57] Seigniorage is defined as the revenue earned from the issue of money. According to Bheemaiah (2017) there are three sources of seigniorage for central banks in a fiat system. First, the difference in denomination of a given money and the production cost. Secondly, when commercial banks arein need of liquidity they reduce deposit holdings in the central banks, consequently reducing the interest on these deposits. Third, seigniorage stems from the proceeds of repurchase agreements made with commercial banks.

As a result of the latter, the sum of the value of bank notes in circulation and CBDC would likely be larger than the value of bank notes in circulation currently and this would increase seigniorage revenue[58], as we will see during the lecture.

Researches and projects

Many central banks have explored the optimal way to launch their digital currency because they took in consideration several salient risk of taking a passive and inertial approach:

1. Equilibrium determinacy: if paper currency becomes obsolete and the central bank does not produce any form of digital currency all payment will be made using privately-issued money.
2. An analysis of Fernandez-Villaverde and Sanches (2017) indicates that the economy may be subject to indeterminacy and that there may not be any equilibrium that exhibits stable prices. In contrast, his analysis finds that price stability can be assured by the issuance of CBDC in conjunction with an appropriate monetary policy framework.[59]

3. Loss of monetary control: if paper currency becomes obsolete and that the monetary base solely comprises banks' reserves held at the central bank. The interest rate on reserves (IOR) provide a floor for the interbank lending rate and it is linked to market interest rate because with a sufficiently high degree of reserves pins down the level of market rates. It is important to have an interest-bearing CBDC that can be held by anyone and ensures the central bank's ability to manage market interest rates over time and continue to adjust monetary conditions as appropriates.

4. Systemic risks: in absence of competition the entire payment system might well become quasi-monopolistic and any significant operational problem within the payment network could pose substantial risks to the entire financial system and to the macroeconomy.

5. Susceptibility to severe downturns: in the absence of an interest-bearing CBDC, the effective lower bound could pose an even tighter and more lasting constraint on conventional monetary policy, which would in turn limit the effectiveness. In such circumstances, the central bank of a small open economy might still be able to provide stimulus via foreign exchange operations aimed at depreciating its currency, but such an approach could prove infeasible or untenable for larger economies. Even though,

[58] Barrdear and Kumhof (2016) argue that interest-bearing CBDC would lead to a large increase in demand for central bank liabilities, which would lead to an increase in seigniorage, and, in turn, to larger residual transfers to the government. They also note that with such a large shift into CBDC, the central bank would need to hold more government bonds on its balance sheet. This increased demand for government bonds, other things being equal, would increase bond prices and lower associated bond interest rates, thus reducing government funding costs.

[59] This is flagged by central bankers: for example, Nicolaisen (2017) specifically warns about the risks associated with a scenario in which the Norwegian economy no longer has any functional legal tender.

central bank might provide stimulus through credit subsidies or by financing public infrastructure nut the viability of such monetary-fiscal policy is highly dependent on the vagaries of politics. Thus, in the absence of CBDC, the central bank might find itself with no real policy alternatives and the severity of the economic down turn could be devasting.

In light of these considerations, a passive and inertial approach towards CBDC may not be the most prudent strategy. Rather, many central banks in both advanced and emerging market are now moving expeditiously in considering CBDC and in investigating its logistical and technical details. The following section describes CBDC initiatives and ongoing research projects undertaken by central banks.
In terms of e-currency design approach, method, technology and involvement of stakeholders, central banks are moving at different speeds: this creates a potential risk for spillover effects across borders.
But the caution and collaboration with they are working hard will reduce the likelihood of unintended consequences. (CPMI-MC (2018))
As said before, a study of Bank for International Settlement shows that 70% of 63 central bank interviewed are conducting research into CBDC. The survey was conducted in 2018 and the main objective was to understand if they work on CBDC and, if they do, it further inquiries about the type of CBDC and how advanced the work is. The characteristics of scalability, interoperability, accessibility, security and flexibility play an important role in the design of all proposed CBDCs and involve them to work on (Olson (2018)).

Many of them are progressing from conceptual work into experimentation and proofs-of-concept to test new technologies also with the cooperation between other central banks. Even though, only five of them are conducting pilot e-coin projects and have intentions to issue a CBDC within the next decade. This is could be due to the lack of current infrastructure limits. Beyond the short term, an increased proportion of central banks consider the issuance of both type of CBDC to be possible.

E-Krona

Probably, it is the most advanced and well-known project. In Sweden, the decline of cash is advanced and it seems possible that e-Krona would not be based on distributed ledger technology as the Swedish Central Bank does not consider the technology sufficiently mature (Sveriges Riksbank (2018)). The project starts in 2017 and e-Krona is defined as “general electronic means of payment” and as a “complement to cash”, no-interest-bearing, available to the general public 24/7. It is unclear whether e-Krona would be token-based and the value would be stored on a card or in an app or account-based and it would be stored in accounts at the central bank. Both types assume that there is an underlying register so that it is possible to record transactions and safeguard who is the rightful owner of the digital krona. It will be possible that the solution is a mix of two models: the

token-based for small offline payments and will make the CBDC accessible to un-banked individuals and account-based will satisfy the payment services needs for banked individuals.

E-Peso

The e-Peso is a digital currency that was issued by the central bank of Uruguay on November 2017 and circulated in the country until April 2018 in order to test CBDC. The pilot plan was needed for verification of technical issues and to keep risks under strict control. 20 millions of Uruguayan Pesos circulated in the economy for 6 months. The use of the digital currency was restricted to the first 10,000 individuals who downloaded the e-peso application on their smartphone and registered to the experiment and, since the pilot was going to last only six months, random, monthly, monetary incentives were enacted in order to make more transactions. Only two kinds of transactions were permitted by the system: peer-to-business payments between users and registered business and peer-to-peer transfers between users. The transactions were made anonymously but the data could have been decrypted if it was required by a competent authority in prosecuting someone. The settlement was instantaneous and does not require internet connection but just a mobile phone line. If users lose their phone or password of digital wallet, e-Peso are well secured because it employed a dual schema of communications to provide a secondary authentication. Moreover, to avoid double spending and falsification, each digital bill had a serial number. At the end of the six months the pilot resulted to be a very positive learning experience, developed according to expectations and there were not technical incidents. According to Mario Bergara, ex-president of the Banco Central of Uruguay, the e-Peso could bring innovation and competition in the financial sector and security and efficiency in the payment system will be significantly improved with the introduction of a CBDC.

Project Jasper

The bank of Canada is working on “Project Jasper”. It is a collaborative research initiative between the public and private sectors. In particularly, the areas of interest were the potential implication of DLT for:

- financial market infrastructures (FMIs) that acts as the trusted third party between financial institutions, tracking and recording transactions in centralized ledgers.
- wholesale payment systems. Actually, in Canada 175 $ billion in payments are processed every business day so it is important to analyze how the use of DLT could change the way for payment system policy.

In 2016, Payments Canada, Bank of Canada, R3[60] consortium, initiated this experimental project to explore a DLT-based wholesale payment system with the goal to build a proof-of-concept system that leveraged a settlement asset issued and controlled by a central bank. In phase 1 and 2 the project focused on exploring the clearing and settlement of high-value interbank payments using DLT. In particular, participants built a

[60] International consortium of large banks with the goal to investigating and developing application of DLT for the financial sector.

settlement capability on a DLT platform and demonstrated its ability to exchange an asset between participants incorporating a liquidity-saving mechanism that allow participants to coordinate their payments to reduce liquidity needs. The restricted system shares a full copy of the ledger with all participants of R3 consortium. In this way the validation function ensure that all details of the transactions are correct and the sender has the required funds. In this project the only notary was the Bank of Canada that had access to the entire ledger so that it can verify that the funds involved in a transaction are available. In conclusion the project Jasper enabled a better understanding of the roles and responsibilities of the operator of a DLT wholesale payment system. By integrating other assets on the same ledger as payments could simplify clearing and settlement across a range for financial assets. For example, exchange-traded assets already clear and settle through safe and efficient systems and gains would be possible if these systems could be integrated by having cash on the same ledger as payments to settle the cash leg of each transaction. In this way could increase cost savings and reduce back-office reconciliation work.

Project Ubin

The Monetary Authority of Singapore (MAS) took in consideration the potential benefits with Project Ubin in 2016 focused on new method of conduction cross-border payments using CBDC, in this case a tokenized Singapore Dollar. The name is Ubin because is the name of a Singapore island that supplied much of the granite that provided the foundation for bilateral trade and relations.

In particular, the first phase consisted of a research and feasibility study around the potential application of blockchain technology, the phase 2 on how to use platforms and tokenization in the daily settlement and clearing process and the last one the potentials of a tokenized national currency and realizing cross-border payments. In conclusion, on 2018 the project ended successfully and they demonstrated how a tokenized dollar could function as a means of daily inter-bank settlement through developing a software prototype for this inter-bank payments with liquidity savings mechanisms, likely to project Jasper. Moreover, the reduction in settlement time allowed command for a trade and the execution of that trade to happen simultaneously, protecting investors.

At the end we can say that the two projects, Ubin and Jasper, show that central bank money can be transferred on a distributed ledger in real time, in realistic volumes and with a liquidity-saving mechanism (Bech and Garratt, 2017).

Project Stella

In December 2016, the European Central Bank and the Bank of Japan contributed on the debate with their project. The phase 1 analyzed the processing of large-value payments using DLT, phase 2 investigated securities delivery versus payment. The latest phase used the insights gained from the previous two phases to

bring the research into the broader sphere of cross-border payments, due to the fact that multiple jurisdictions are involved and they are often characterized as slow and costly.
The main result from the first two steps is a mitigation of credit risks through the synchronization of settlement. Regarding safety and efficiency, the phase 3 concludes that only payment methods with an enforcement mechanism can ensure that the transacting parties completely satisfy their responsibilities in the transaction process.
A last press release of ECB in December 2019 stated that ECB will continue to analyze CBDC with a view to exploring the benefits of new technologies for European citizens because the desirable design features and its economic financial implication warrant further analysis.

Other researches

The Central Bank of Ecuador, which adopted the US dollar as legal tender in 2000, tried to launch their digital currencies in 2014 (Dinero Electrònico (DE)). In 2015 DE acted as a functional payment method, permitting users to perform payment transactions and to transfer money through a smartphone application. Moreover, it helped to reduce government's cost incurred in printing notes[61]. Nevertheless, in March 2018 the government dismissed the digital currency. The reason was the failure of the government to attract enough users.[62] People did not use digital currencies due to the lack of trust in government consequently of the dollar default in 2008. So, citizens are involved to think that dollars deposited at a private commercial bank were less risky than dollars deposited at the central bank. This is the reason why it is important to increase trust and credibility before launching a new form of legal tender.

The People's Bank of China (PBOC) has initiated the project in 2015 and seems to become the first[63] country to issue a CBDC controlled by the central bank and backed one-to-one by the country's fiat reserves. In December 2019, Chinese media reported that the central bank was planning to conduct the first real world test of its CBDC. The digital currency could be integrated into the existing banking system, with commercial banks operating digital wallets for the retail CBDC and the general public able to conduct peer-to-peer transactions like with cash. Yi Gang, the governor of the People's Bank of China, said the plan was not to create a new currency but to partially digitize China's existing monetary base, or cash in circulation, and balances by payment apps such as WeChat and Alipay. So, retail banks and fintech companies will continue to manage customer deposits in the same way but, instead of using existing clearing system, the new digital currency

[61] Considering that more than 3 million were spent to exchange deteriorating old banknotes for new dollars annually.
[62] out of the 402,515 accounts that were opened, only 41,966 were ever used to make payments, 76,105 were only used to upload and download money and the remaining 286,207 remained constantly inactive.

[63] According on Financial Times "What is China's digital currency plan?", 2019.

could provide a neater way to settle payments with each other[64]. The central bank would probably prefer to be in control of the database, so probably they will use a private and permissioned blockchain. Moreover, the digital currency will be issued to existing financial institutions and the commercial banks will distribute it to customers without becomimg a threat for retail banks.

A Tunisian governmental financial institution has intention to issue a blockchain-based digital token called "e-Dinar" since 2015. The digital tokens are currently used in Tunisia to transfer funds, pay for goods and service online, pay for salaries and bills, and manage official identification documents with limited costs. The new digital tokens will be issued in a decentralized manner through the proof-of-stake process by the miners, maintaining the anonymity. Even though, the issue on this latter will be not imminent.

Instead, Ernest Addison, the governor of the Bank of Ghana, revealed that the bank is working with key stakeholders to explore a pilot CBDC project. Even though, he did not mention whether the digital currency would be based on blockchain technology but the bank would create electronic value backed by an equivalent cash amount, which will allow customers to have access to electronic wallets issued by GCB.
Ghana is not the first country in Africa to consider the benefits of issuing its digital currency, also the National Bank of Rwanda announced it was researching how to offer an official digital currency in order to increase transaction efficiency and foster economic growth. Due to the fact that banks are not spread allover the country, the unbanked individuals would join the same possibility of banked one. In this way, there will a strong positive impact on economic growth.

Venezuela is the only country that has issued a digital currency sponsored by government (e-pedro) in 2018 and is backed by a barrel of oil from the country's oil reserves. The digital coins are complementary to the bolivar as legal tender. US President Donald Trump reacted to this initiative by prohibiting transactions using the digital coin because it seemed to circumvent the financial sanctions imposed by the US by attracting foreign investors in the face of severely disrupted economic and financial conditions. Even though, due to insufficient information, it is not clear if digital currency is going to be dismissed.

Regarding US, the FED did not identify "potential material benefits of general purpose CBDC to the implementation of monetary police relative to our existing tools" (Jerome Powell, 2019) furthermore stopped Libra project.

[64] Settlement is the actual exchange of money or some other value for the securities. Clearing is the process of updating the accounts of the trading parties and arranging for the transfer of money and securities.

Future outlook

Even though, something seems to change. Six central banks (Bank of Canada, Bank of England, the Bank of Japan, the European Central Bank, the Sveriges Risksbank, the Swiss National Bank) have created a working group to share central bank digital currency experience. All six banks already have significant expertise in exploring digital currencies. As you can note, apart from Bank of Japan, three Asian central banks (People's Bank of China, Monetary Authority of Singapore, Bank of Thailand) are not part of the group despite having CBDC research experience. A press release on January 2020 stated that the group will be co-chaired by Benoît Cœuré, Head of the Bank for International Settlements Innovation Hub, and Jon Cunliffe, Deputy Governor of the Bank of England and Chai of the CPMI and will assess economic, functional and technical design choices, sharing the knowledge on emerging technologies. There is no inference that this group might explore a "synthetic hegemonic currency", so a digital currency made up of a basket of currency issued by central banks.

How CBDC can fulfill the role of money

Through the three basic functions of currency (store of value, means of exchange and unit of account) we will be delineating the capacity of CBDC to perform these functions and act the role of money.

Store of value

To perform as a store of value a currency has three options:

1. Constant nominal value, as for paper currency;
2. Constant real value, indexed to price level;
3. Earn interest like short-term government securities;

In the first case, since the new currency would not earn any interest, there will be less radical change in macroeconomics and financial framework. In the second option, it could be indexed to price level as to maintain constant its real value and for example to control inflation.
The final option, CBDC deposit accounts would accrue interest just like government securities. This leads to the possibility for central bank to set a nominal negative interest rate in adverse economic conditions and eroding the value of deposits. The latter could increase the actions for central bank monetary policy in low or close to zero inflation scenario. However, cash is likely to be abolished to prevent that households hold only cash against negative nominal rates imposed on digital currency deposits. More likely there would be different interest rate levels: this would give the possibility for banks to earn much higher interest rate and use it as a mechanism for the monetary policy.

Efficient medium of exchange

To be an effective medium of exchange, the currency must have:

1. Certain degree of acceptability
2. Legal tender
3. Trust of consumers

Anyway, there are two type of cost that can be distinguished:

1. External costs: Fees and commissions paid within the payment system;
2. Internal costs: resources and the services involved in the payment process (e.g. POS terminals).

These costs are split between banks, schemes and retailers[65] and often paper currency has a significant cost in illegal operations (e.g. money laundering and tax evasions).
The future issuance of CBDC have notable costs but marginally these costs decrease. It will lead to a change in the type of costs that will become costs of verification and costs of networking. The first one is correlated to the ease of validation that has a significant impact on the scalability of the platform and its intensity of usage. The second one is related to the usage and it includes the cost of managing the network infrastructure. Also, it is important to take in account the cost in term of energy.

Today, the only form of currency which is publicly available to all citizens and firms regardless of their characteristics is paper currency. To cover this role CBDC must be central bank-issued, with zero-commission peer-to-peer exchanges and without necessary having to rely on a financial intermediary but with the requirement of an electronic distribution feature.
Two scholars, M. Bordo and A. Levin, described two different action plans. The first one involves public authorities promoting the diffusion of the newly issued CBDC and fostering its adoption within business and households. To do so, it is necessary to adopt some incentives: a direct public investment into IT infrastructure and state subsidies to allow the distribution of hardware and software required at a low price increasing the adoption rate and widespread diffusion.
The second one it focuses on the development of a gradual fees schedule for converting CBDC into cash. This will be useful to facilitate the gradual obsolescence of paper currency.

[65] For example, 2012 study from the Bank of Italy found that Italy spends around 8 billion to printing and renewing paper and metal currency.

Stable unit of account

To facilitate economic and financial decisions making of individuals, the primary objective of ECB's monetary policy is to maintain price stability that enhance spending and saving decision efficiency.
In a market economy, prices are mostly set by private economic actors so the only way to reach the price stability goal is through the setting of a proper monetary policy. When the real value of CBDC is stable this mean that the central bank is reaching a positive inflation target strategy (2%).
By contrast, with the adoption of interest-bearing CBDC, the central bank could establish a constant price level target that would be a natural focal point for expectations and hence serve as an enduring and credible nominal anchor. Of course, as with inflation targeting, the price level target would need to be specified in terms of a particular price index, but that specification would not be modified subsequently except for compelling technical reasons. To facilitate transparency, the index would ideally be constructed from publicly-posted prices of final goods using a published methodology that would be reproducible by private-sector analysts. Moreover, to ensure continuity over time, the index would utilize chain-weighting rather than relying on any specific base year.

Regarding this, the next section will analyze possible monetary and banking policy effects of the introduction of such new CBDC.

Implication in Monetary policy

We consider how a central bank digital currency could transform all aspects of the monetary system and facilitate the systematic and transparent conduct of monetary policy.

Obviously, the consequences of CBDC issuance for the implementation and transmission of monetary policy are directly related to how wide access to CBDC is and whether it is attractively remunerated.

In fact, if CBDCs were remunerated, its interest rate would become a key instrument for implementing conventional monetary policy. It would affect household and corporate saving and investment decisions, either directly, through the renumeration of funds deposited at the central bank, or indirectly, by setting a lower bound on the renumeration of bank deposits.

We will deal with the change in monetary policy and the effects on transmission mechanism from different point of view. We will discover how problems, like zero lower bound, could be avoid and seigniorage could importantly increases. Finally, we examine the future effect of monetary policy on agents' balance sheet and the possible term structure of interest rate. Furthermore, study how unconventional monetary policy tools could be impacted by the introduction of CBDC.

Effects on monetary policy and transmission mechanisms

Problem of Zero Lower Bound

If cash were eliminated, also the main reason that justifies the existence of the so-called zero lower bound could disappear. The problem refers to the difficulty of financial institutions to set negative remunerations on retail bank deposits, since in that case agents might withdraw their fund and save through the accumulation of banknotes. In fact, the costs associated with banknote storage mean that these rates may be slightly below zero, but they cannot be arbitrarily negative. This is a limit for expansionary monetary policies in an environment of low interest rates, because can lead to a liquidity trap.

Conversely, in the case of an economy without physical banknotes, the CBDC interest rate would mark the floor on interest rates. That would break the current existence of the zero lower bound allowing bigger cuts in nominal rates, whenever it is necessary although there are already low rates.

Monetary policy could beneficiate of the pass-through of the policy rate to money markets and deposit rate and helping to alleviate the zero (or effective) lower bound constraint, through CBDC that stimulates the expenditure during periods of downturn (Andrew Haldane, 2015).

A central bank's liabilities define the quantity of so-called base money in circulation and the interest rate of reserves. When the interest rate nears zero, the only possibility for the central bank is to use unconventional policy tools[66].

A CBDC could remove the ZLB problem because negative interest rates could be payable on CBDC. For example, Dyson and Hodgos (2016) argue that "*if digital cash is used to completely replace physical cash, this could allow interest rates to be pushed below the zero-lower bound*". This argument was developed in detail by Rogoff in 2016: by allowing to overcome the zero-lower bound and therefore freeing negative interest rate policies (NIRP) of its current constraints. Only digital central bank money can allow for strong monetary stimulus in a sharp recession or financial crisis. Obviously, this could not only avoid recession, unemployment and deflation but also the need to take recourse to non-standard monetary policy measures which have more negative side effects than NIRP.

In the hypothetical scenario of introduction of non-remunerated CBDC, the remuneration of commercial banks' reserves at the central bank would continue to mark the floor for short-term interest rates in the interbank market.

[66] Such as Quantitative Easing where the central bank purchases assets (government bonds) with newly created central bank money to stimulate spending and investment.

Additional instrument

A number of authors have argued that variable interest rates on CBDC would provide a new monetary policy instrument that would allow improving the overall effectiveness of monetary policy. In fact, Barrdear and Kumhof (2016) supported a thesis that "*a CBDC regime can contribute to the stabilization of the business cycle, by giving policymakers access to a second policy instrument that controls either the quantity or the price of CBDC in a countercyclical fashion. This second policy instrument becomes especially effective in response to shocks to private money demand and private money creation".* They formalized the use of interest rates on CBDC as an independent macroeconomic monetary policy tools in a state-of-art monetary model[67]. They confirm that the introduction of new monetary policy framework could raise the country steady state level of GDP by around 3%, thanks to a drop in real interest rate, a reduction in distortionary tax rates and also lower transaction costs.

Meaning et al (2017) analyze how CBDC could enrich the monetary policy toolkit and how it would impact the transmission mechanism and come to the conclusion that it would all depend on the details of the design of CBDC. Finally, Berentsen and Schar (2018) argue that interest on CBDC would simplify monetary policy as the "*central bank would simply use the interest rate paid on these accounts as its main policy tool*".

On the other hand, the European Central Bank observed and explain in a working paper of January 2020, that from the practical perspective of central bank operations, the interest rate of CBDC may not be perceived as an independent monetary policy instrument but rather as an instrument similar to the other spreads between ECB policy rate and the renumeration rates of a specific deposit accounts. These rates (or spreads relative to the key policy rate) may pursue specific objectives in terms of incentivizing behaviors of those for which these rates are relevant, including e.g. incentives to rely on the central bank vs. relying on market-based alternatives, with repercussions on the central bank balance sheet and on market functioning . They are not perceived as independent contributors to the monetary policy stance. The (overnight) interest rate on central bank reserves anchors the short end of the risk-free yield curve and has established itself as the one and only operational target of monetary policy (Bindseil, 2014).

The various European Central Bank operations rates (e.g. the rate of the main refinancing operations, the rate of lending, the rate of the deposit and the zero rate on the remuneration of banknotes) are all not perceived as independent monetary policy rates.

What matters for monetary policy in the end is the level of short-term market rates, and in particular the overnight interest rate on bank reserves with the central bank, as anchor of all other market interest rates. This principle, for the ECB, should not change even with the introduction of CBDC.

In fact, the remuneration rate on CBDC would be chosen such that it would have, in normal times, a sufficient negative spread likewise the short-term risk-free market rates, so that CBDC would not become a large-scale

[67] "The macroeconomics of central bank issued digital currencies" John Barrdear and Michael Kumhof, July 2016.

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

Similarly, Mancini-Griffoli et al (2018) take the view that CBDC is unlikely to affect the main channels of monetary policy transmission[68]. There are four transmission's channels:

- The basic interest rate channel may be the most affected and could strengthen. Changes in policy interest rate induce households and firms to rebalance investments and consumptions between the future and the present, especially if these are exposed to interest-sensitive borrowing and saving instruments. If CBDC increases financial inclusion, as we noted before, also monetary policy transmission could strengthen the gain would be most evident if CBDC were interest bearing.
- The bank lending channel could also strengthen. In fact, through this channel policy interest rates and their expectations affect bank balance sheets and profits and consequently their creditworthiness and thus their deposit funding cost and lending rates.
- The credit channel is unlikely to be affected much: policy rates affect asset prices and collateral values of borrowers, thus their creditworthiness and costs of borrowing, but CBDC should not markedly impinge on these effects.
- The exchange rate channel that brings balance between foreign and domestic assets and a variation in the exchange rate affecting exports and imports is unlikely to be affected. This view depends also on the expectation that central banks would remain in a position to affect market interest rates relevant to the channels above. First, central banks should be able to affect term spreads through communication as before, such as by releasing and discussing their interest rate projections. Second, central banks should be able to retain control of interest rate on reserves. As long as banks demand reserve balances to pay each other, the central bank should be able to set their marginal price. Since the price of reserves determines the opportunity cost for banks to lend funds to each other, and the rates set in money markets affect rate on riskless and also risky assets, the presence of banks across these markets is essential to transmission and CBDC is not expected to markedly affect any of these conditions.

[68] The same view is taken by ECB in last working paper on January 2020.

Some adjustments may nevertheless be necessary to central banks' operating frameworks. CBDC is likely to displace cash but could also partially drain reserves from commercial banks if customers withdraw deposits to hold CBDC. Central banks would still be able to replenish these, if banks need the reserves for precautionary purposes, by engaging in liquidity-injecting open market operations. Ultimately, demand for precautionary reserves might actually decrease, because CBDC could attenuate the variance of payment shocks (unlike cash, CBDC does not require lumpy withdrawals from costly visits to ATMs) or increase their predictability. But even if the shape of the demand curve for reserves change, central banks should be able to adapt their supply of reserves to stabilize interest rates. In the interim, movements between deposits and CBDC could be volatile and require more frequent liquidity-injecting open market operations, perhaps on a fixed-rate full allotment basis, to stabilize interest rates. A floor system could also be considered to stabilize interest rates, since the demand for liquidity does not need to be accurately forecast. In the scenario that central bank lost the business of CBDC and they were no longer involved in intermediating payments, demand for reserves would disappear. But even in a cashless world monetary policy has the means to remain effective. In fact, Woodford (2000) argues that "*perfect control over overnight rates would still be possible, through adjustments of the rate paid on central bank balances*". Paying interest on CBDC involve a put a floor on interest rates and no one with access to CBDC would lend at a rate below that offered by CBDC, and it would remain the safest and most liquid asset available. This is the same of control monetary policy by paying interest on reserves when these are in excess of what is demanded by the banking sector for precautionary purposes (referred to as a "floor system").

However, given that the CBDC is an alternative to current accounts as a store of value and means of payment, the renumeration would indeed be an effective floor for the rates at which the different economic agents with access to CBDC lent funds to banks.

Likewise, the remuneration on CBDC would establish a lower bound for interest rates on households' and firms' deposits. Thus, changes in the CBDC rate would affect agents' spending and saving decisions, either directly the remuneration of funds deposited at the central bank, or indirectly through their effect on the remuneration of deposits at commercial banks. In turn, changes in banks' funding costs affect the interest rates at which banks lend to the real economy. In short, the remunerated CBDC scenario would afford the central bank greater control over the general financial conditions in the economy and, therefore, over aggregate demand.

Seigniorage

Beyond its effects on monetary policy transmission, the pressure that remunerated CBDC would exert on the returns on bank deposits might have implications for the profitability and size of the banking sector.

Seigniorage is the profit made by the central bank from its issuance of currencies, in particular the face value minus production and distribution cost. In a two-tier banking system, income from issuing money (banknotes

and deposits at commercial banks) partly accrues to commercial banks, giving way to a broader notion of seigniorage. It could be affected if CBDC will be remunerated or not and obviously will decline if demand for currency decreases.

There are two channels through which broad seigniorage value may change due to CBDC:

1. CBDC affects the overall value of the money issuing because it reduces operational costs (related to printing, storage and transportation of banknotes, and settlement costs) and, especially at the outset, entails significant fixed infrastructure costs but very low marginal costs.
2. CBDC may serve as a substitute for other non-deposit financial assets (shares in money market mutual funds). This latter effect would increase money in circulation and thereby broaden the overall seigniorage base.

Moreover, seigniorage depends on two key variables: the stock of currency in circulation and the difference between central bank assets and currency liabilities. Introducing CBDC could change both of them. Any CBDC-driven expansion of the balance sheet has a positive effect because most the funding cost equals the policy rate (i.e. the risk-free rate). Any asset that the central bank may buy from, lend to, or accept as collateral from its monetary counterparties should have an expected yield above the expected risk-free rate over the investment horizon. As a CBDC-driven expansion of the balance sheet entails a corresponding decline of retail deposits and money market instruments, such increased central bank seigniorage corresponds to decreased seigniorage income at banks and money market issuers. This effect may be offset to some degree if CBDC were to lead to reduced demand for banknotes, which are non-interest bearing. As we can see in the following part, the impact would depend on the remuneration of CBDC. In fact, in the case of a sufficiently low CBDC interest rate relative to the rates on bank reserves, banks could offer deposit rates above the CBDC rate, thereby avoiding the loss of deposits, and at the same time maintain the profitability of its funds.

At the opposite extreme, a CBDC interest rate at the same level as that on bank reserves would force banks to raise the remuneration on their deposits above the CBDC rate. This, in addition to reducing their net interest margins, might lead to a reduction in the supply of credit and raise the cost thereof, likewise leading in all probability to a contraction in the banking sector's intermediation capacity.

Actually, the cash's share in payment amount is decreasing and its decline continue to happen. But in a scenario where the future demand for CBDC match or exceed the existing demand for cash could increase the seigniorage. Conversely, this will lead to a decline of the central bank's profit and any significant reduction of seigniorage would constrain their ability to recapitalize following financial losses, in the absence of other sources of income. The persistence of low or even negative capital could put monetary policy and financial stability at risk.

Effects on Balance Sheets

According to the vision of the Committee on Payments and Market Infrastructures (2018), the presence of CBDC would have a limited impact on monetary policy implementation. Central banks use an overnight rate to achieve its operational target. The financial institutions that are directly relevant to this operational target and its transmission to money market are the central bank's monetary counterparties. In fact, central banks need to ensure that the value of attracting or trading away overnight funds from monetary counterparties equals the operational target.

Two operational regimes are typically used:

1. A corridor system.

Central banks apply two interest rates to reserves: up to a limited amount (depending on reserve requirements), the policy rate is applied and beyond that a lower deposit rate is paid.

Monetary counterparties may access an overnight lending facility at a higher rate. Central banks need to ensure via open market operations (OMOs) that the overall amount of reserves equals the overall limit amount at which the policy rate applies. Central banks can increase flexibility in fulfilling this requirement by applying a band at which the policy rate is applied instead of a limit or the minimum required amount of reserves averaged over a maintenance period.

Central banks must forecast the demand for liquidity in order to be prepared to inject (or drain) the right quantity of reserves. This involves projecting day-to-day changes in autonomous factors: all the balance sheet items outside of the direct control of the central bank's monetary policy implementation function that affect the amount of reserves. The difference between the policy and the deposit rate provides an incentive for monetary counterparties to trade overnight funds among themselves, on a secured or unsecured basis. Such transactions take place to the policy rate. Thus, policy rate becomes the marginal value of attracting or trading away overnight funds from monetary counterparties, while the overall amount of reserves can be relatively small. This enables central banks to run a lean balance sheet as we can see from figure n°18: a balance sheet that is only slightly larger, limiting the intermediary role of the central bank.

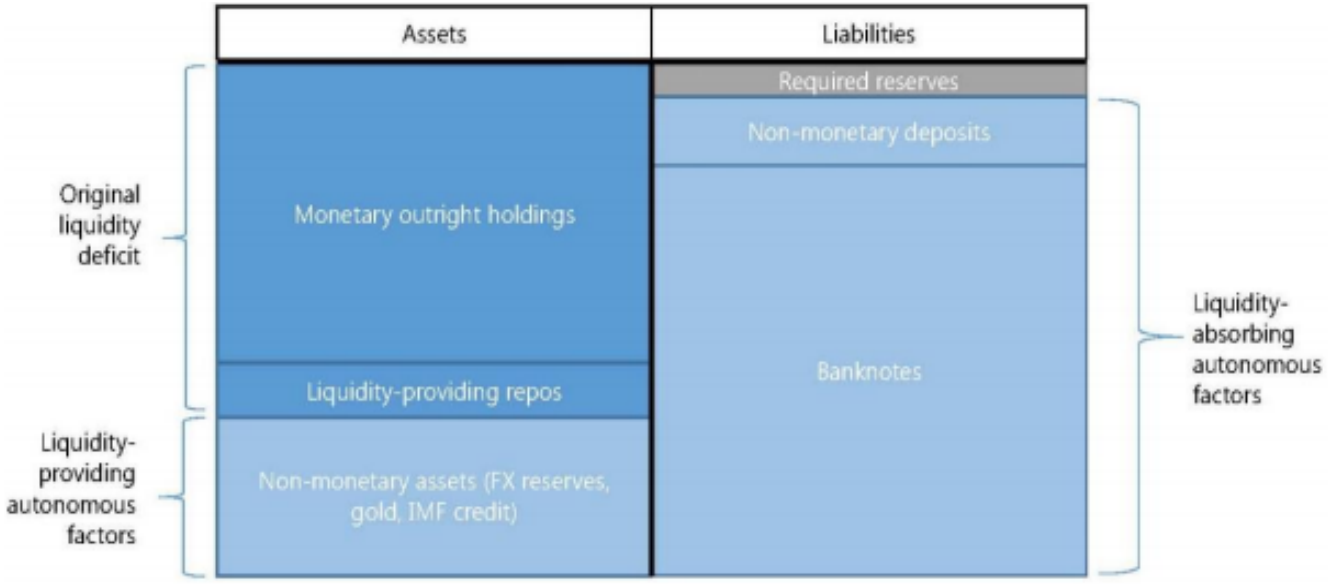

Figure n°18- Corridor System Without CBDC (Source: BIS)

2. *A floor system.*

Central banks ensure that the marginal value of attracting or holding overnight funds from monetary counterparties equals the deposit rate. With substantial excess reserves, the marginal use for monetary counterparties of holding additional reserves is to earn the deposit rate that become *de facto* policy rate. To achieve this, monetary outright holdings must exceed the original liquidity deficit, i.e. the liquidity needs caused by net autonomous factors. Liquidity forecasting is less important because day-to-day fluctuations in the amount of reserves do not change the marginal value of attracting or holding overnight funds.

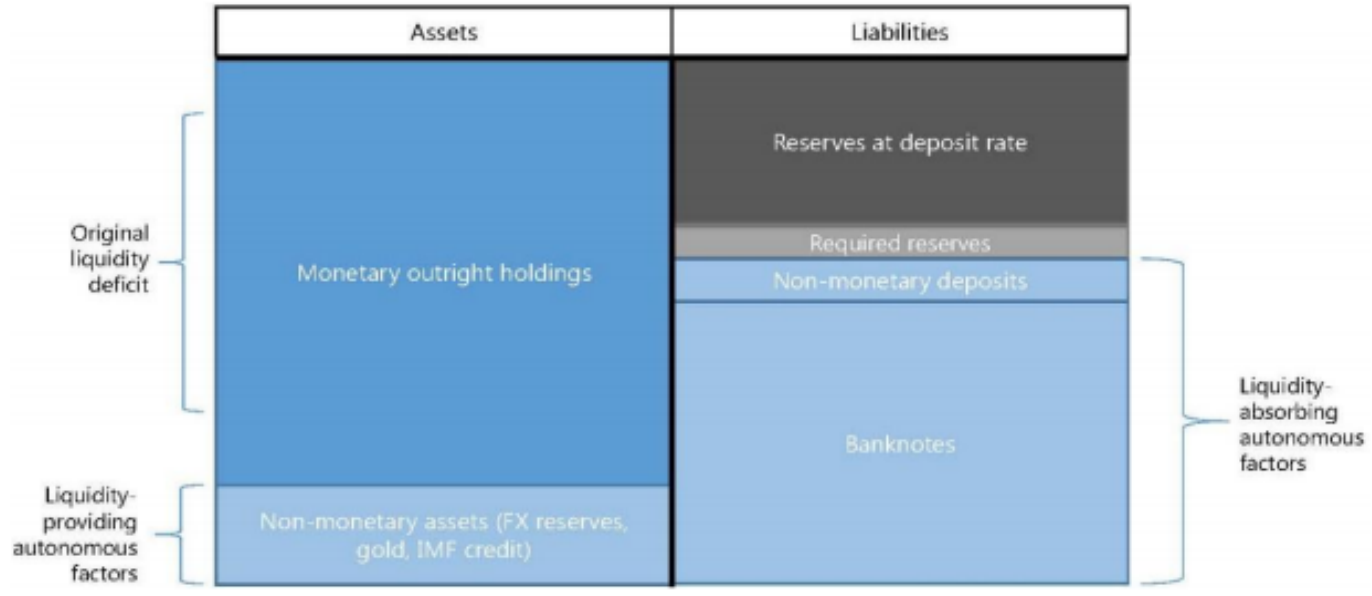

Figure n°19- Floor System Without CBDC (Source: BIS)

In both operational regimes, flows into non-monetary deposits that is digital central bank money held by non-monetary counterparties (e.g. the treasury, foreign central banks or FMIs) and banknotes result in a drain of reserves.

In a corridor system, such flows need to be compensated by liquidity-injecting OMOs. In a floor system, such flows only need to be compensated if the liquidity surplus becomes insufficient and rates begin to rise above the deposit rate (monetary outright holdings threaten to fall below the original liquidity deficit).

In practice, flows into banknotes are limited by the carrying cost of cash, making banknotes relatively inconvenient as a store of value. Flows into non-monetary deposits are typically limited by price disincentives beyond certain specified amounts, also making non-monetary deposits relatively unattractive as a store of value. Such price disincentives are often applied to limit the central bank's intermediary role. Different central banks put varying weights on this principle, however, and apply different price disincentives and access conditions to non-monetary deposits.

A stylized balance sheet of the central bank after the introduction of CBDC is depicted in figure n° 20, reflecting the demand for CBDC and its increased assets holdings.

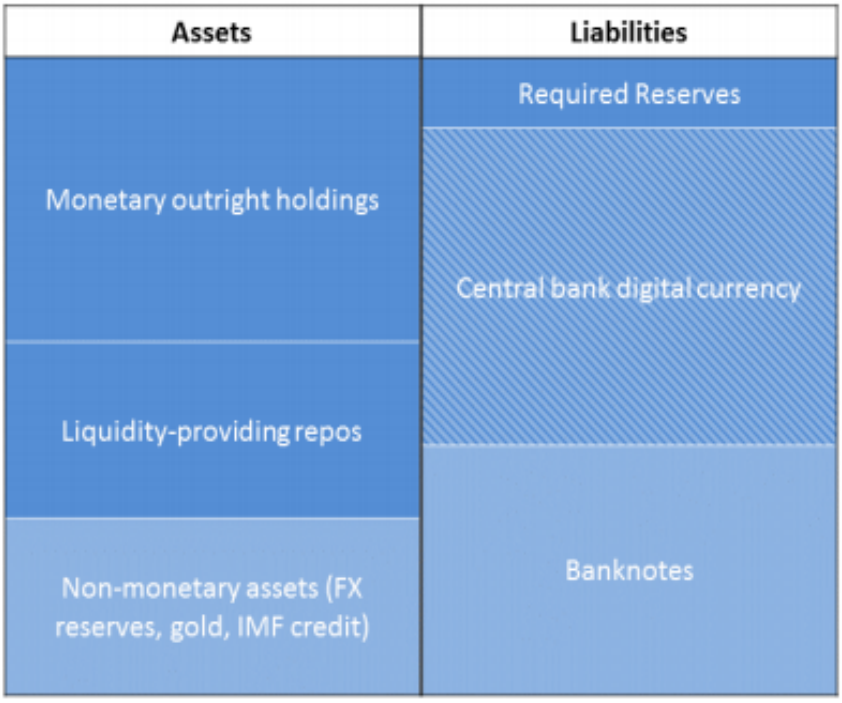

Figure n°20-Central Bank Balance Sheet with CBDC (Source: BIS)

While a central bank would need to accommodate demand for CBDC, flows into CBDC would drain the amount of reserves in the system in the same way as flows into banknotes and central bank deposits held by non-monetary counterparties (e.g. the treasury, foreign central banks or financial market infrastructure) currently do.

As we noted before to compensate all flows in and out and to keep the desired amount of reserve, in a corridor system, it will be necessary open market operations and , in a floor system, it will be necessary undertake additional liquidity-injecting OMOs only when CBDC inflows drained reserves to the point where they became scarce.

Therefore, CBDC does not alter the basic "mechanics" of monetary policy implementation.

A flow-of-funds analysis by BIS illustrates how sectoral balance sheets and the implementation and transmission of monetary policy may be affected by the introduction of a general purpose CBDC. The analysis is performed under the assumption of a central bank operating through a corridor system.

As you can see in figure n°21, the balance sheets considered are those of:

- Households (retail): they hold real assets (RA), retail deposits at commercial banks (DEP) and banknotes (BAN). Furthermore, they invest in corporate/government and bank bonds (B+BB) and money market fund share (FS). Moreover, they finance themselves through retail mortgage loans (RML) provided by commercial banks on their own funds or equity (E).
- Corporations/government fund themselves via bank loans (L) and bonds (B) as well as money market instruments (MM). This sector holds real assets (e.g. public infrastructure, corporate facilities) and liquidity buffers in the form of cash pool participations (CPP).
- Banks (monetary counterparties) funding takes place by accepting retail deposits, by issuing money market instruments (e. g secured funding via repos or unsecured funding via commercial paper) and bank bonds and by drawing on central bank credit facilities. These instruments fund purchases of government and corporate bonds, loans to corporates, retail mortgages to households and holdings of central bank reserves (RES).
- The central bank. The liability side of the central bank's balance sheet consists of banknotes held by households and reserve balances held by banks. On the asset side, the central bank has outright holdings of corporate, government and (covered) bank bonds and provides credit to banks, therewith implementing monetary policy.

The analysis aimed that the introduction of CBDC opens up several channels that may affect patterns of financial intermediation in the economy.

1. Households may substitute banknotes for CBDC (CBDCa) which prompts a change on the central bank's liability side.
2. Households may substitute retail deposits for CBDC (CBDCb) by making payments from retail deposits to CBDC accounts.

Because of such payments, banks request the central bank to debit reserves held by them and credit the CBDC accounts. In order to ensure that reserves stay at the required level to implement monetary policy, the central bank buys bonds or provides additional credit to banks.

In the analysis, the central bank accommodates CBDC inflow by increasing its lending to monetary counterparties and outright holdings of bonds. The banks use the central bank's funds to compensate for the lost retail deposits (CBDCb). In this highly restrictive scenario, there is only a shift in intermediation and no impact on the real assets held by corporates/governments and households. Instead, the central bank intermediates between households, on the one hand, and banks and corporate/government, on the other.

In practice, some funding losses and gains and thereby some degree of deleveraging and/or leveraging are likely to happen as central bank credit leads to bank asset encumbrance. This, in turn, is costly to banks and may induce them to reduce their loans and bond holdings. To the extent that the shift in the structure of financial intermediation provokes higher (lower) liquidity, term and credit-risk premia on the funding for households and corporates/government, their capacity to hold real assets may decrease (increase).

Households (retail)			
Real assets	RA1	Equity	E
Retail deposits	DEP – **CBDCb**	Retail mortgage loans	RML
CBDC	**CBDCa + CBDCb**		
Banknotes	BAN – **CBDCa**		
Bonds (for investment)	B1 + BB1		
(Money market) fund shares	FS		
Corporations/government			
Real assets	RA2	Loans	L
Cash pool participation	CPP	Corporate/government bonds	B1 + B2 + B3
		MM instruments	MM1
Banks (monetary counterparties)			
Corporate/government bonds	B2	Retail deposits	DEP – **CBDCb**
Loans	L	MM instruments	MM2
Retail mortgage loans	RML	Bank bonds	BB1 + BB2
Reserves	RES	CB credit facilities	RES + BAN – B3 – BB2 + **CBDCb**
Central bank			
CB credit facilities	RES + BAN – B3 – BB2 + **CBDCb**	Reserves	RES
		Banknotes	BAN – **CBDCa**
Corporate/government/bank bonds	B3 + BB2	CBDC	**CBDCa + CBDCb**

Figure n°21-CBDC and the structure of the financial system: a flow-of-funds analysis (Source: BIS)

Demand for CBDC would just be another factor to consider for policy responses to be consistent with continued control over short-term interest rates.

There are only two practical implications:

- Depending on the degree of substitution, a larger balance sheet may be needed to implement monetary policy, as agents substitute physical cash, commercial bank deposits and other safe assets for CBDC.
- The overall volatility of autonomous factors could be affected, which in turn, may affect their predictability.

To conclude, central banks would have discretion in choosing the assets they hold to accommodate the demand for CBDC, just as they have for banknotes. Theoretically, assets can be made up of outright holdings of any kind or collateralized lending to monetary counterparties on any terms and conditions. Subject to the overall supply of various types of asset and change thereof, the additional duration, liquidity and credit risk stemming from accommodating the demand for CBDC is thus determined by the central bank itself, as in the case with banknotes.

Demand for CBDC may be volatile on a daily basis, as inflows and outflows result from payments between CBDC and non-CBDC holders. The quality of liquidity depends on the predictability and forecasting of daily flows in and out of CBDC. This leads to higher overall volatility depends on the correlations with other factors[69] and if forecasting in and out flow of CBDC become particularly difficult, central banks can be forced to operate through a floor system.

Term structure of Interest Rate

According to the Committee on Payments and Market Infrastructures, the overall effects of CBDC on the term structure of interest rate are very hard to predict and will depend on many factors. To attract demand, short-term government paper and overnight repos with treasury collateral might have to provide some yield pickup with respect to a wholesale-oriented remunerated CBDC. This means that the short end of the sovereign yield curve may end up above the CBDC rate. Contrary to the hard floor that the wholesale CBDC variant may put under money market rates, the general purpose variant is likely to put only a soft floor under retail deposit rates given the lower price sensitivity of retail depositors and switching costs.

At the same time, depending on the specific assets held to accommodate the issued CBDC, central banks would probably need to engage in various kind of maturity, liquidity and credit risk transformation. How these two forces balance out in terms of various interest rates across assets classes and maturities are likely to depend on each jurisdiction's specific operating environment. Also, since operating environments may change in the future, monetary policy cost-benefit analyzes related to CBDC may need to be revisited periodically.

According to Bindseil (ECB), CBDC must have a tiered[70] remuneration because, as he said, the "*rather simple solution, tiered remuneration, can solve the problem of quantitative control and thus of undue bank*

[69] In the case of a corridor system, this may necessitate more frequent liquidity-injecting and liquidity-absorbing OMOs, higher reserve requirements with averaging provisions or wider tolerance bands around reserve targets to steer liquidity conditions.
[70] Actually, Japan and Denmark, already have a tiered structure.

disintermediation. At the same time, this solution allows the central bank to commit to never applying negative rates on an amount of CBDC that seems sufficient to allow CBDC to play a key role in payments and if the remuneration rate for tier-two deposits is sufficiently unattractive, then the amount of such deposits should be low, or even zero". The implication seems to be that holders would not prefer digital over traditional fiat or to use the digital to make a run on banks. Thus, a structural risk for disintermediation might be neutralized.

Unconventional monetary Policy

Quantitative Easing

This unconventional monetary policy is used to inject liquidity in the economic system. In recent years central banks have purchased assets from the private sector and fund these purchases with newly created central bank money.

But non-banks cannot currently hold electronic central bank money so must use commercial banks to sell asset to the central bank. The commercial bank sells the asset to the central bank on behalf of the non-bank and receives an increased balance of electronic central bank money in its reserve account. This generates a new deposit on the liability side of its own balance sheet and credit to the ultimate seller, so the non-bank. A universally accessible CBDC would remove this need of intermediation and QE could be carried out directly with non-bank participants.

The central banks can purchase an asset from a non-bank and simply increase the balance on the seller's CBDC account. In this way QE could become more targeted and central bank can choose to alter the balance sheet of the non-bank or banking sector independently. As shown in figure n°22, a central bank could increase the aggregate supply of CBDC in the economy by purchasing financial assets from the non-bank private sector or from the banking sector and paying for these assets with newly created CBDC. The non-bank sells an asset, the bond, to the central bank, transferring the bond to the central bank. The central bank pays for this asset by issuing new CBDC, which is credited to the CBDC account of the non-bank. In the right column, the central bank balance sheet has expanded, since the new asset is matched by a new liability (bond vs CBDC). For the non-bank private sector, one asset has been replaced by another and, so while the composition of its assets has changed, the total quantity of assets has no changed.

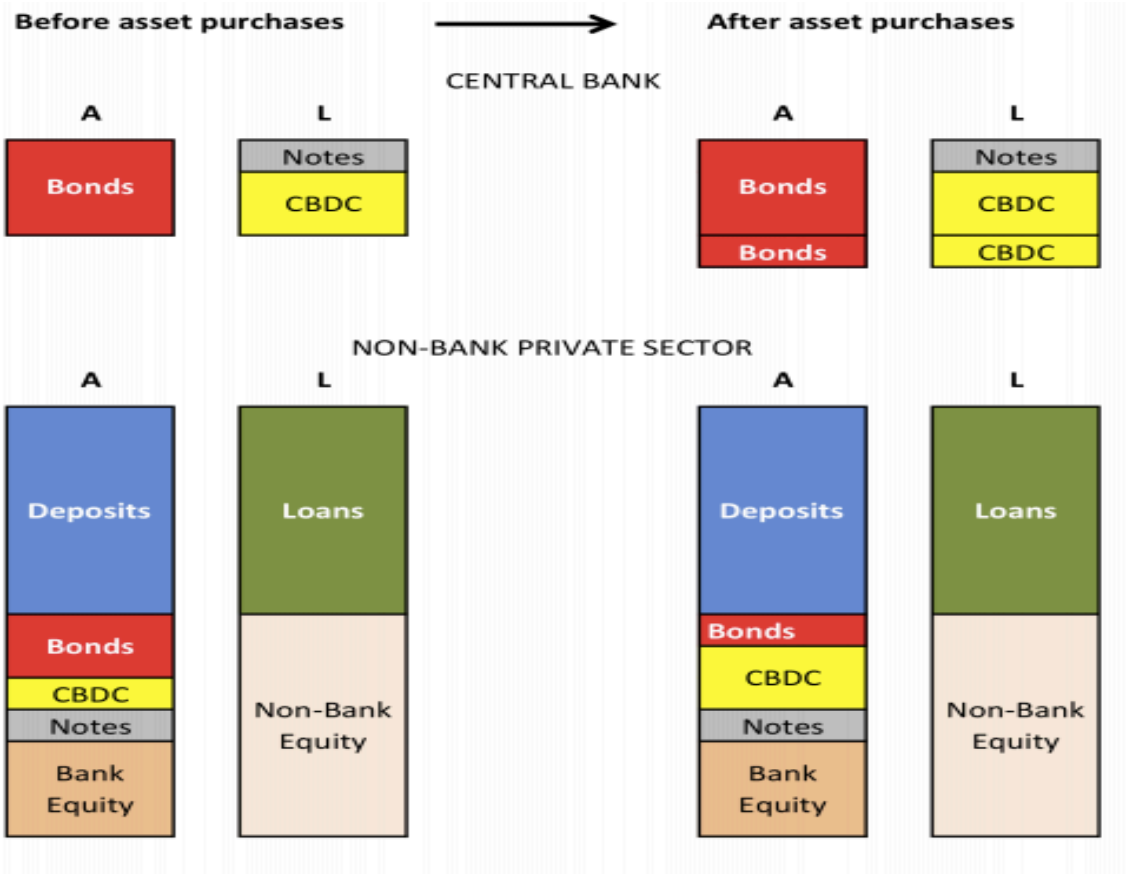

Figure n°22-Mechanism of asset purchases under CBDC system (Source: Bank of England)

Helicopter money

This expression refers to an unconventional monetary policy used to be an alternative to quantitative easing (QE), when economy is in a liquidity trap[71]. Milton Friedman was the first that coined this term in the paper "The Optimum Quantity of Money" in 1969 and he wrote a parable of dropping money from a helicopter to illustrate the effects of monetary expansion. Originally, the term was used to illustrate the effects of monetary policy on inflation and the costs of holding money, then was used by economist to introduce an alternative monetary policy instruments, rather than quantitative easing, that would be more efficient to increase aggregate demand in a situation of liquidity trap, when central banks have reached the zero-lower bound, mentioned before[72]. He argued that "*Let us suppose now that one day a helicopter flies over this community and drops an additional $1,000 in bills from the sky, which is, of course, hastily collected by members of the community. Let us suppose further that everyone is convinced that this is a unique event which will never be repeated*." In this way, each citizen receives a certain amount of cash for free and is believed to be a powerful instrument in deflationary scenarios. Like other expansionary policies, this involves money creation by central banks to expand the money supplies but the effect on the central bank's balance sheet is different. Basically, under QE,

[71] When interest rate near zero, injecting liquidity in the economy to avoid recession is not useful.
[72] Also, Mario Draghi in 2016, ex-president of the European Central Bank, said that he found the concept very interesting.

central banks create reserves by purchasing bonds or other financial assets[73]. This mechanism can be reversible, by contrast, with helicopter money, central banks give away the money created without increasing assets on their balance sheet, creating permanent effects.

Moreover, Dyson and Hodgson (2016) argue that "*digital cash can be used as a tool to increase aggregate demand by making <helicopter drops> of newly created digital cash to all citizens, making it easier to meet the Bank of England's monetary policy target of price stability*". Because a CBDC would be universally accessible, it would give central banks an easy way of transferring money to the real economy without the need for the financial system as an intermediary. Obviously, this argument is supported and shared by who agree on helicopter money. Even though, it is clear that facilitate the distribution of money but it cannot be a pre-condition to use this tool.

To make clearer the way digital cash can be useful, Dyson and Hodgson make an example: "*Imagine that, in the middle of a recession, the Bank of England's Monetary Policy Committee surveyed the economy and realized that the high level of household debt, and low level of business confidence, meant that simply lowering interest rates would not be sufficient to increase borrowing (so increasing money creation by the banks) in order to boost spending and aggregate demand. Instead, they decide that the most effective way to boost demand would be to give every single citizen a one-off grant of £1,000, to use as they wish. Each citizen must provide details of one bank account into which the payment will be made. (We'll leave aside the logistical challenges of this process for now.) Suppose 10 million citizens nominate their current account at Royal Bank of Scotland (RBS). The Bank of England would credit RBS's reserve account with £10 billion (£1,000 x 10 million people) of newly created reserves, and RBS would credit each of those 10 million deposit accounts with £1,000 of newly created deposits. The process would therefore create £10 billion of new deposits in the hands of the public, which they could spend. Note that this process would not improve the financial position of RBS in any way: both its assets (the reserve account at the Bank of England) and its liabilities (the 10 million deposit accounts) would have increased by the same amount, so RBS's net worth would be unchanged[74]".*

However, the problems that could arise are the following:

1. Currently, the Bank of England pays interest to banks on the central bank reserves they hold that it is 0.5%. Banks pay 0% or very close to zero percent interest on deposits. This mean that, as a result of helicopter money in the current system, banks would acquire risk-free interest-bearing reserves and a corresponding amount of almost interest-free deposits. The interest they would earn on these reserves would therefore effectively be "free money" for the banks, since they would not have had to take any risk.

[74] Note that this process would not improve the financial position of RBS in any way: both its assets (the reserve account at the Bank of England) and its liabilities (the 10 million deposit accounts) would have increased by the same amount, so RBS's net worth would be unchanged.

2. Due to the fact that reserves are remunerated at 0.5%, issuing helicopter money in the current system would incur an ongoing interest cost for the central bank and in turn for the government. This would mean that, from the perspective of government finances, helicopter money would have a similar cost to simply borrowing money through the markets by issuing bonds.
3. It is desirable to avoid paying interest on the reserves issued through helicopter money and to differentiate interest-bearing and non-interest-bearing reserves. But this would complicate the reserves system.

Assuming that no interest would be paid on digital cash, the introduction of digital cash issued by the central bank would allow helicopter money to be implemented without creating these problems.

Conclusion

One of the effects of the sharp loss of public trust in financial markets after the crisis was the search by some participants for alternate marketplaces[75]. The demand was satisfied by technologies that would not rely on centralized bodies, including authorities and global banks, to provide trust to transactions, to approve and record transactions. Also, in some cases, a portion of market participants has delinked the value of such transferrable assets from the direct influence of central banks and, in the post crisis era we have seen the rise of tradable crypto-assets[76], backed by a distributed ledger technology referred to as blockchain. After several market incidents and following various communications by market authorities raising concerns over the trading and resilience of the pricing in the crypto-asset markets, valuation have fallen considerably. In response to the shortcomings in these forms of crypto-assets, in 2019 there has been an increase in industry announcement to issued so-called "stablecoins", which are cryptoassets that are pegged or backed by real assets such as commodities or fiat currencies or economic index in order to reduce volatility by anchoring the "coin" to a reference asset or a basket of assets. Therefore, it is raised the need of a debate to give further consideration to centralized digital currencies backed by central banks. However, since the development and adoption of innovative technologies also bring potential risks, continued structural changes in the financial sector, combined with periods of market volatility and market stress, could expose underlying vulnerabilities associated with financial innovations.

In fact, the main object of this thesis was to analyze the impact of a cryptoassets backed and issued by a central bank on the overall financial system with a focus regarding the implication on monetary policies. In this framework, contrary to common wisdom that state that this phenomenon could cause disintermediation of banks, banks should have several advantages if they move on the right way and carefully evaluate how to change their business model in order to exploit the disruption.

As we have seen during the thesis, central banks can not only have advantages but also increase financial stability and overall welfare if ride the wave in best optimal way with a right design and well issue of the digital currencies. In fact, a low interest-bearing CBDC can improve bank intermediation and set a floor for the deposit rate under the zero-lower bound. But it can happen only if the interest rate is set properly.

Moreover, it is not only about monetary policy, in fact CBDC could decrease the costs associate with a national means of payment, providing a safe and liquid government-backed one denominated in the domestic unit of account. Among the main reasons, it can enhance the resilience of the overall payment

[75] Blundell-Wignall 2014

[76] Entire market rose from under USD 10 billion in 2015 to peak at nearly USD 700 billion in 2017, as Bitcoin alone rose to a market capitalization of USD 300 billion (OECD, 2019).

system and the currency, supported by distributed ledger technology, would facilitate automatic payments when assets are delivered using smart contracts.

To conclude, financial system is becoming more and more elaborated and, consequently, also financial intermediation. The social welfare increased due to the innovative new means of payment that lead to easier and faster transactions. Central banks do not need to fear as long as private inside money is denominated in sovereign currency and there is the right regulation and structure. At the same time, they do not put a brake on innovation and have the capacity to ensure that implications set the right course for the economy, for business, for citizens, for society as a whole (Carstens, 2019). From a legal prospective, in particular PSD2 that provided the framework of the whole payment services in Europe, the legislator and the state promote more competition and innovation giving a third trusted party (TTP) the possibility to satisfy demand, more than supply, of more efficient payment services. What is going to happen with the new players in the banking field will be an innovation of banking offers and costs of all services are going to change. But it is important to underpin that banks can take advantage of their position being the major trusted agents and enlarge their own objectives to build a business model adapted to satisfy this new social necessity, as it had always done.

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Abstract

The aim of this thesis is to analyze the potential and future impact of a central bank digital currencies on financial and monetary system. Before start to describe this new type of "sovereign money" and the consequently implication, it is important to focus on the motivation behind.

In fact, depending on what you want to achieve then you would design the currency in a specific way and the design would have different implications. The strong relationship between these factors involve the necessity to understand the framework from different point of view.

We are living in an era where digital technology has brought innovation in many sectors, including the financial one. The growing relevance of different digital payment's methods and the declining usage of cash can cause a financial earthquake and change the status quo.

The proliferation of FinTech (Financial Technology) is reshaping economic activity spurring a new digital forms of money and makes under pressure central banks that have to face with a new model of financial intermediation and transmission of monetary policy. It passed more than 20 years since Bill Gates opined "*Banking is essential, banks are not*" but this thesis aim to demonstrate how instead banks is essential and can play a decisive role if they will stay "*ahead of curve*", how Christine Lagarde said. Contrary to common wisdom, that state that this phenomenon could cause disintermediation banks do not need to fear but they have to move on to satisfy this new social necessity, in particular build higher public confidence. It is fundamental since money works because people trust in its value so in the government and in central banks. In Golden Standard system, you could exchange banknotes issued for golds but when the link between notes and gold was broken money did not have intrinsic value anymore, except the paper or metal used in production of money. Anyway, the agents have trust in the medium of exchange because the system promise that the issued money can be used to settle liabilities in the economy. European Central Bank defines "*fiat currency as any legal tender designed and issued by a central authority that people are willing to accept as money being well regulated and trusted*". It allows itself to adjust the money supply in response to changes in money demand and, when it is necessary, can conduct monetary policy to ensure price stability and a sound, robust financial system. Nevertheless to work it needs the trust of the agents, who need to know that received money are not rejected in future transactions and does not decrease significantly in purchasing power. If depositors lost trust, the bank runs cause severe liquidity crises and accelerate the failure of these institutions, causing huge losses and disrupting the economy. One of the main effects after the crisis in 2007 was the loss of public trust in financial markets and the research by some participants for alternative marketplace. The demand was satisfied by technologies that would not rely on centralized bodies, including authorities and global banks, to provide trust to transactions. In the new digital era in which there are blockchain and other distributed ledgers technologies (DLTs) parties with no particular trust in each other can exchange any type of digital data on a peer-to-peer basis, with fewer or no third parties or intermediaries. Also, in some cases, a portion of market participants has delinked the value of such transferrable assets from the direct influence of central banks and,

in the post crisis era, we have seen the rise of tradable crypto-assets, backed by a distributed ledger technology referred to as blockchain. Distributed ledger technology, of which blockchain is a subset, is a database (ledger) for storage data (or for instance money, insurance policies, contract…etc) replicated (distributed) over a peer-to-peer network and that enables multiples parties to share the database and modify data or transactions in a safe and secure way, even they do not know the other one. When a ledger update happens, each node constructs the new transaction and the nodes vote by a consensus algorithm on which copy is correct. Once a consensus has been determined by every network's users, all the other nodes update themselves with the new and correct copy of the ledger.

This is the reason why the system is considered "trustless" and avoid asymmetric information. Agents are able to conduct transaction with strangers simply by trusting the cryptography and mathematics rather than middleman. There is no longer any center and the logic of governance is built around a new concept of trust between all the subjects. No one has the possibility to prevail and the decision-making process strictly passes through a process of building the consensus.

Blockchain is distributed ledger technology in which transactions are recorded in batches, or "block" validated by every computer belonging to the network through a consensus mechanism with cryptographic tool and protocol rules, called mining. Every transaction will constitute a new "block" added, or "chained", to the old one in order to amend the existing ledger with additional transactions. The whole process ensures that each block is created in a way that irrefutably links it to the previous one and the next one, forming a chain of blocks or blockchain. We can distinguish four major blockchain types based on its characteristics:

- Public permissionless: everyone can participate in the blockchain's consensus mechanism, make transactions and see the blockchain's transaction history.
- Public permissioned: everyone can transact and see all transactions, but a restricted number of nodes can participate in the consensus mechanism.
- Private permissioned: the ability to transact and view the transactions to only the participating nodes in the system and the architect or owner of the system determine also who can participate in the blockchain system and which nodes can participate in the consensus mechanism.
- Private permissionless is restricted in who can transact and see the transactions while the consensus mechanism is open to everyone.

Let's see the major features of this technology:

1. Decentralization: there is not a central entity that controls the system, but everyone follows a set of rules, or consensus mechanism, to verify, validate and add transactions to the blockchain. Moreover, there is not a central point of failure and the existence of multiple and distributed nodes makes the system very resilience and very difficult to attack[77].

[77] However, public and permissionless blockchain can handle a limited number of transactions and the validation means high energy consumption. Moreover, it can bring attacks if a group of participants controlling a majority of computational resources. Instead, in

2. Tamper-resistant: it is extremely difficult to change or delete the record of transactions and every modification is visible to everyone. Only if there are the consensus by the majority (50 + 1 per cent) of participants there will be a possibility to delete or change the history of transactions[78].
3. Transparency: everyone with an internet connection to the network has the same rights to access and update the ledger, previous consensus by all of participants belonging to the network.
4. Security: the main advantage is to keep track and verify information in a secure way. Data is linked publicly to a certain date and time, so no one can modify what has been recorded and time-stamped.
5. Smart contracts: "*Smart contracts are computer programs that are capable of carrying out the terms of agreement between parties without the need for human coordination or intervention*" (Buterin, 2015). The idea of self-executing contract was presented by Nick Szabo in 1997, in the article "The Idea of Smart Contracts". He exemplifies the idea of a vending machine to figuratively present smart contracts. Everyone who has the money to pay for a product can buy it for the given price and the product and the money is secured from intruders by the features of the machine. As is well known, trust is the core of blockchain, intrinsic in his system. So, it provides a foundation for applications. The agreements of the contract can be recorded and validated into a blockchain which can then automatically execute and enforce the contract under "if-then" instructions: if something happens (for example if you pay) then certain transactions or actions are carried out (you will have the product). This brings to remove the need for a trusted third party to function as an intermediary. The way in which transactions are verified and added to the blockchain guarantees that conflicts or inaccuracies are reconciled and that in the end there is only one valid transaction (no double entries).

After having explained the main features of Blockchain, it is also important recorded the challenges remain until unresolved:

1. Limited scalability and performance of public blockchains.

   Mainly related to the low volume of transactions or the high energy consumption when deploying PoW (Proof of Work) consensus mechanisms.
2. Potential attack.

   Other threats can arise from potential collusion from a majority of participants which could overrun the network (50 % +1% attacks) or from the high dependency of running the network on a limited number of participants[79].
3. Key management.

a permissioned system that thing do not happen cause a preselected group of participants have the power of validation. But this lead a weaken of the concept of decentralization and it can be considered centralized or semi-centralized model.

[78] Tamper-resistant does not involve the characteristic of immutability and unchangeability, even though it is very hard to change: one of the most controversial cases was 'the DAO hack' in which the theft of funds was restored through a community decision to split or 'fork' the underlying record.

[79] In, for example, permissioned blockchains.

A major source of security vulnerability also lies in the responsibility of keys, which can be as simple and serious as losing a phone or a back-up of the credentials.

4. How to safeguard personal, sensitive or confidential data.

   Transparent data on a blockchain might be a problem when specific data sets are not meant to be publicly available, or need to be changed due to errors, inaccuracies or other problems in the original data entry (European Commission, July 2019).[80]

Let resume the pros and cons, already mentioned, of this type of technology.

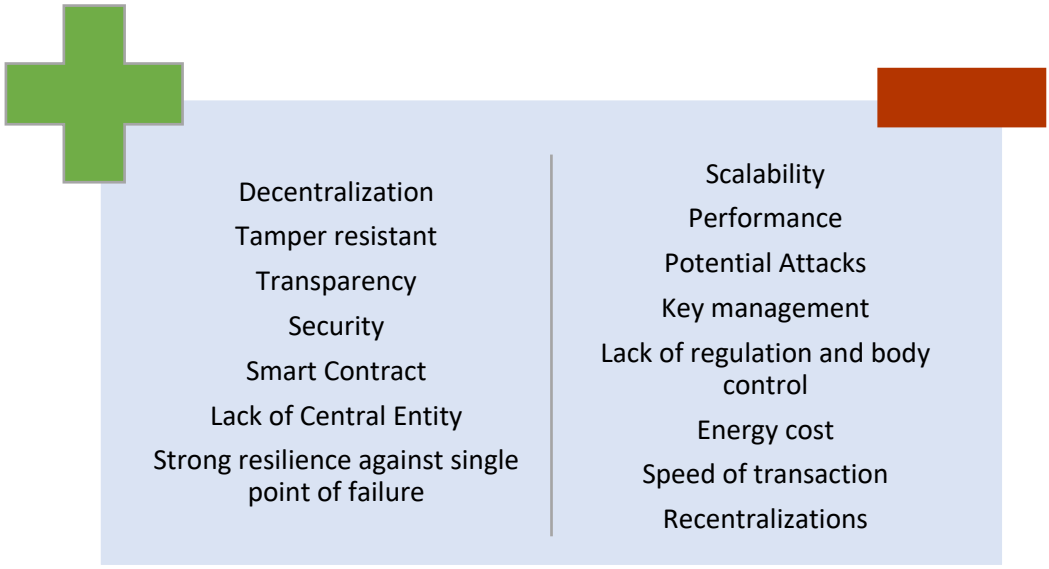

Figure A- Pros and Cons of blockchain.

Blockchain technology started with the development of crypto-currencies. These are a medium of exchange, created and stored electronically in the blockchain using cryptographic techniques (mining process) to control the creation of monetary units and to verify the transfer of funds not subject to the control of a state authority. Bitcoin is the best know example and was the first cryptocurrencies created. It is not a coincidence that it was introduced in the aftermath of the Lehman Brothers' crisis. Precisely on third of January 2009 the source code of Bitcoin was released within which a message that criticized the current financial system that was to collapse and need the government bailout: "*Chancellor on brink of second bailout for banks*".

Bitcoin does not have intrinsic value in that it is not redeemable for another commodity[81], it does not have physical form[82] and exist only in the network and its supply is not determined by a central bank and the network is completely decentralized.

It can be for these reasons a medium of exchange but bitcoin performs poorly as a unit of account since bitcoin-based quotes for prices of ordinary goods and commonly extend to "*four or five decimal places with leading zero, a practice rarely seen in consumer marketing and likely to confuse both sellers and buyers in the*

[80] "*Potential conflicts between specific blockchain architectures and the EU's GDPR warrant a wider debate*."
[81] Its value is not supported by the status of legal tender but it is solely determined by the trust that each person holding it has.
[82] Blockchain is only a ledger in which there is a history of all transactions. Physical money does not exist and it is not stored anywhere: the coins are only accounting item and the final balance is made by calculation between all transactions of an users.

marketplace". Even then, due to its high volatility it does not work as a store of value but more as a speculative asset. The major difference between fiat digital currencies, in fact, and cryptocurrencies are the following:

1. Decentralization: no single institution controls the bitcoin network, but it is maintained by a group of volunteer coders and run by an open network of dedicated computers spread around the word. It solves the "double spending" of electronic currencies through combination of cryptography and economic incentives. Since there is not a single authority bitcoin are not a liability of anyone. This is the main difference is that fiat digital currencies represent liabilities of a central banks while cryptocurrency does not represent a financial claim on, or a liability of, any identifiable entity. In fact, European Central Bank has defined cryptocurrency as a "*new type of asset recorded in digital forms and enabled by the use of cryptography that does not represent a financial claim on, or a liability of, any identifiable entity*" (ECB Crypto-Asset Task Force (2019)).
2. Limited supply. Bitcoin has limited supply: the maximum quantity allowed of bitcoin is around 21 million. Instead, fiat currencies have an unlimited supply and central banks can issue many as they want and can attempt to manipulate a currency's value relative to others. This makes bitcoin more attractive as an asset because if demand increase the value consequently rise but not as a role of money. This could lead a deflation: when bitcoin rise until the maximum quantity, inflation will fall to zero and miner could earn only from fees of transactions.
3. Pseudo-anonymous. Sender of traditional electronic payments are usually identified, users of bitcoin in theory operate in semi-anonymity. Since there is no central validator, users do not need to identify themselves when sending bitcoin to another user. When a transaction request is submitted, the protocol checks all previous transactions to confirm that the sender has the necessary bitcoin as well as the authority to send them. Each user is identified by the address of his or her wallet, so the system does not need to know his or her identity. But if it is strictly necessary, the identity users can be identified. This makes bitcoin not an ideal currency for criminals, terrorists or money-launderers.
4. Immutability. Bitcoin cannot be reversed, unlike electronic fiat transactions. If a transaction is recorded on the network, cannot be modify anymore.
5. Divisibility. The smallest unit of a bitcoin is called a "*satoshi*". It is one hundred millionth of a bitcoin (0.00000001), around a hundredth of a cent. This lead to make transaction that with traditional electric money cannot.

To conclude, to replace official currencies they would have to overcome the following challenges:

1. The supply of cryptocurrency would need to act as an instrument that affects the economy, ensuring central bank to fulfil their price stability mandates and inflation targeting;
2. In the presence of fractional reserve banking, the supply would need to respond to liquidity crises and act as a lender of last resort in order to safeguard financial stability;

3. There would need to be a system of checks and balances to keep the agent (i.e. cryptocurrencies issuer) accountable to the principal (i.e. society) which is not possible because cryptocurrencies are automatically and privately-issued.

In response to the shortcomings in these form of crypto-assets, in 2019 there has been an increase in industry announcement to issued so called "stablecoins", which are crypto-assets that are pegged or backed by real assets such as commodities or fiat currencies or economic index to reduce volatility by anchoring the "coin" to a reference asset or a basket of assets. The stablecoins could introduce a new level of confidence and trust, whereby people around the world would choose a global currency over their local regime. For example, Facebook initiated project Libra with the main aim of enhancing financial access for underserved populations and providing faster and more efficient retail payments across borders. Libra will be backed by financial assets such as a basket of currencies and US Treasury securities in an attempt to avoid volatility. Unlike the cybercurrency bitcoin which use a permissionless blockchains, Libra uses a permissioned technology relying on trust in the independent Libra Association[83] as a de facto central bank. This was a "wake up call" for banks that have raised the debate in order to provide a digital form of their currency to the public, as they do with physical cash, called Central Bank Digital Currencies (CBDC). It is electronic, universally accessible, 24x7, central bank issued money. The design features depend on the objectives and motivation of the central bank. Currencies can either be token-based, involving the transfer of an object of value from one wallet into another, or account-based, involving the transfer of a claim recorded on one account to another. The distinction, as you can see in Figure B, between tokens and accounts is in the method of verifying an exchange: the focus of verification for token-based money is the object transferred and the focus of verification for account-based money is the identities of the account holders.

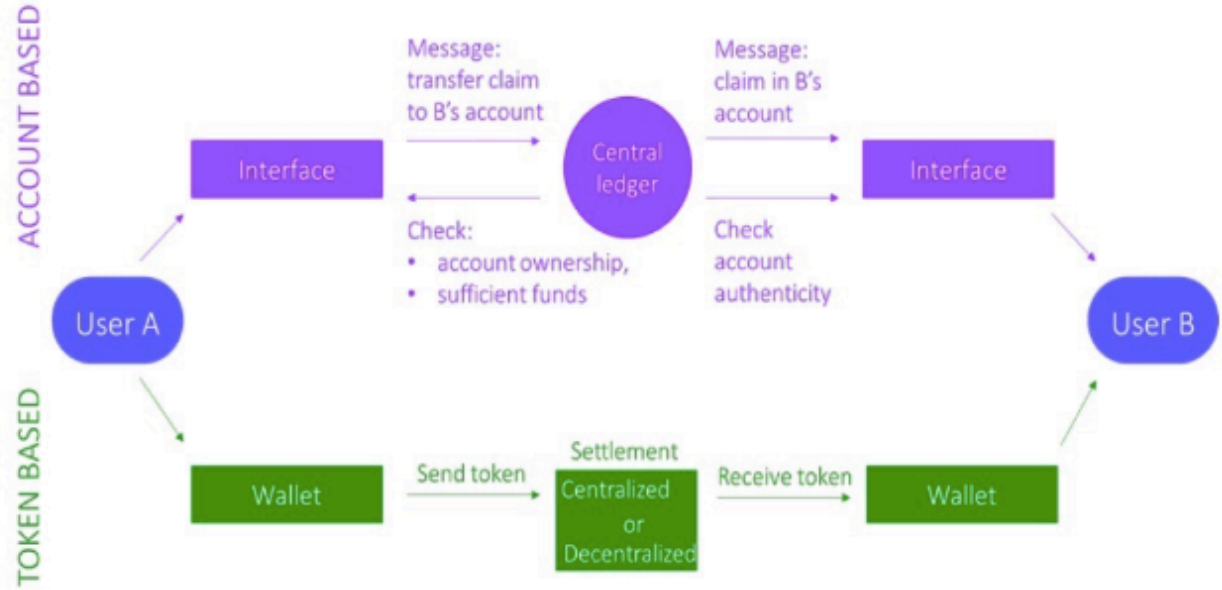

Figure B- Account and Token-Based CBDC, Basic Mechanism (Source: IMF Staff)

[83] a membership organization.

CBDC tokens would use some form of distributed ledger technology for verifying the chain of ownership of each token and validating payment transactions, without requiring the direct involvement of the central bank or any other clearinghouse[84]. Under the alternative design individuals and firms would hold funds electronically in CBDC account at the central bank, or in specially designed accounts at supervised depositary institutions. Both type of design can increase the number of deposit accounts currently offered[85] but the token system involves higher level of anonymity, cause the central bank would not know who currently hold the issued tokens but only the object transferred[86]. In both designs, the degree of anonymity is less than the currently system in fact now central bank money available to retail users (i.e. cash) is completely anonymous while that available to financial intermediaries (i.e. reserve) is note. If it will be used a token system, the blockchain does not record real names but the transactions of the ledger are public and would be traceable to the owner of the wallet and in an account system a third-party anonymity is completely absent. So as, central bank would be able to control the payment system and this affecting the transactions done in the economy also the usage of money for illicit activities. Another important design choice, it is regarding the interest bearing of CBDC. The research department of the International Monetary Fund (Itai Agur Anil Ari Giovanni Dell'Ariccia) studied the optimal design of a central bank digital currency analyzing the impact on the welfare environment if CBDC would be interest-bearing like deposits or not. In fact, a CBDC could compete with deposits and may lead to a decrease of bank credit or if it will be similar to cash may lead to the disappearance of cash so, in order to achieve the optimal design it is important t consider tradeoffs between network effects and financial frictions. The model assume that banks collect deposits, extend credit to firms and create social value in doing so. Households have heterogeneous preferences over anonymity and security in payments: provides anonymity in transaction while bank deposits are more secure. The figure C shows the aggregate welfare impact ($\Delta U = \Delta\pi + \Delta r_d$)[87] of introducing a CBDC across the distribution of household preferences of payment $i \in [0,1]$, where higher value of i denote a grater preference for anonymity and a lesser degree of security and vice versa. $\theta \in [0,1]$ is the optimal rate that a CBDC must have to maximize the users' welfare and it is determined by central banks. T is a lump-sum tax used to fund CBDC.

[84] However, the central bank would determine the supply of CBDC tokens, which would be fixed in nominal terms and serve as legal tender.

[85] In the case of the Eurosystem, the number of accounts could grow from around 10,000 to some number between 300 and 500 million, calculated considering all registered major inhabitants of the euro area, plus firm fulfilling some legal status and/or some minimum criteria on payment or economic activity. (ECB, Tiered CBDC and financial system, Jan 2020)

[86] A straightforward example is a token that represents equity in an organization built on a blockchain platform where "the token-holder receives future cash flows from a successful project" (Hu, Parlour and Rajan 2018). Another example is Nexo, which is a crypto loan company that pays out a portion of the profits to Nexo token holders.

[87] Where $\Delta\pi$ is the profit that the firms could have from an increase of consumption due to a decrease of interest rate and r_d is the deposit rate.

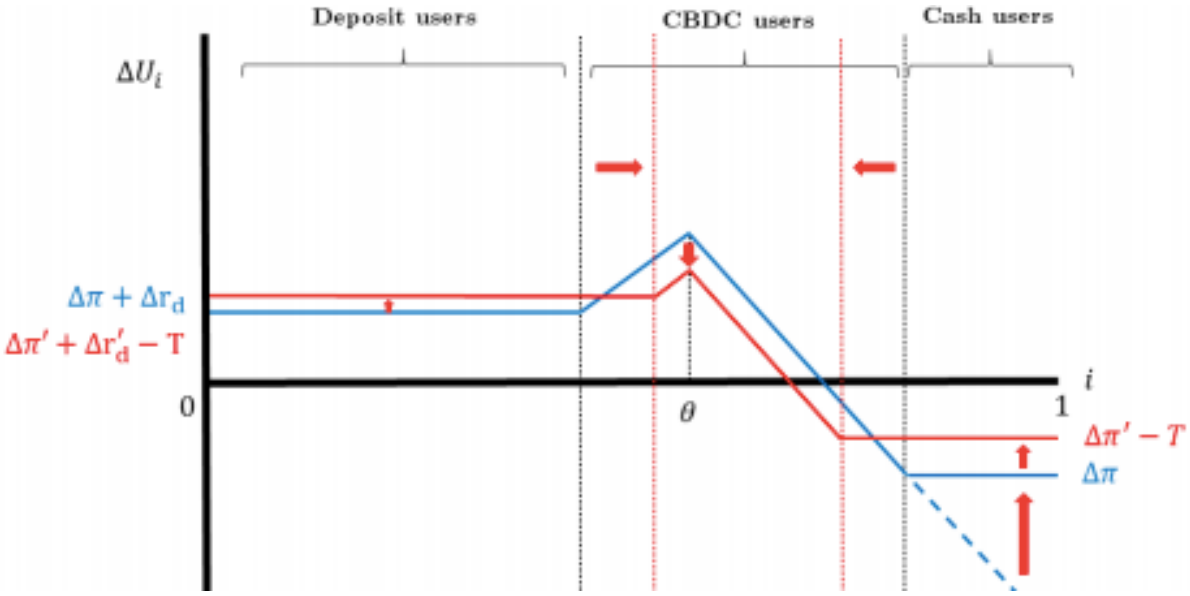

Figure C-Distributional effects of CBDC (Source: IMF Staff)

The blue line depicts the impact of a non interest-bearing CBDC on the utility users' function.

The main consequences of a CBDC with design like cash, it is an inevitable increase in rate of deposit rate. As you can see, households with preferences of safe payments (low i) remain as deposit users after the introduction of CBDC but they will have benefit from positive effects on bank deposits. On the one hand, the increase in deposit rate reduces total production and therefore profit transfers π from firms. On the other hand, CBDC competition with bank deposits drives up deposit rates r_d. Overall, the latter effect that dominates is the raise of the consumption and hence the welfare of all deposit users. Instead, households with a strong preference for anonymity (high i) remain as cash users and the welfare will be impacted through consumption. Since cash does not pay interest, the decline in firm profit π brings a decline in consumptions and welfare for these households. If instead CBDC drives out the use of cash, these households suffer due to the loss of their preferred payment instruments. Moreover, the extent of their welfare loss then becomes proportionate to their preference for anonymity. Households that switch from deposits to CBDC will have a net welfare gain from CBDC introduction. These users will switch to CBDC only if the gains in terms of payment preferences outweighs the loss of interest payment r_d. The households with $i = \theta$ would have the greatest increase in welfare instead for these marginally prefer CBDC over cash, the net welfare effect is negative, since CBDC holders also suffer from a fall in consumption due to reduced firm profits.

At the end, depositors have the main advantage and cash holders emerge as the main losers.

Instead, the red line shows the welfare impact of an interest-bearing CBDC[88].

The revenues from negative CBDC rates are transferred lump-sum to all households, which effectively redistribute welfare gains from CBDC users to cash and deposit users. Negative CBDC rates increase deposits and financial intermediation, firm profits π rise, which benefits all households while deposit rate r_d decreases.

[88] The rate is slightly negative.

However, this second effect of negative CBDC is dominated by the first, in that all CBDC users lose out and deposit and cash users gain from the CBDC rate cut. Finally, CBDC rates prevent the disappear of cash and large loss of welfare for cash holders due to the loss of their preferred payment instrument. To conclude, the optimal CBDC rate diverges from zero and it is slightly negative. When there is no CBDC, deposits and cash are able to coexist, as they do in most countries[89] but, as you can note, an optimally design CBDC rate always raises welfare. Moreover, a survey among 63 central banks[90] of Barontini and Holden (2018) report recognizes three important effects on welfare economy: efficiency, stability and accessibility of payments. CBDC would facilitate online transactions that are currently foregone because of friction that inhibit some types of transactions[91]. At the end, it could lead to a reduction of transaction costs for retail and institutional payment. On the other side, trust in the currency would entirely depend on trust in financial intermediaries issuing and managing commercial money. Moreover, CBDC reduce working capital required for cross-border transaction service, decreasing time to dispute resolution and reconciliation and make speedy and simultaneously clearing and real-time settlement processing. To sum, have a secure and standard instrument o payment backed by a central bank enhance confidence in money system and increase resilience in national payment system. Another effect of CBDC, it is the growth of financial inclusion. Some customer that actually today do not have a bank account[92], could have access to these tools at minimal or zero cost with CBDC. The Global Findex database states that in 2017 1.7 billion of adults in the world remain unbanked, specially from a poorer environment who have been interviewed regarding the reasons. At this regard, David Andolfatto in his paper "*Assessing the Impact of Central Bank Digital Currencies on Private Bank*" has investigated the impact of CBDC on the banking sector. The model demonstrates that CBDC enhances financial inclusion, increasing the number of bank accounts in the economy. The second main finding is that CBDC has no effect on bank lending activity, but it reduces banking monopoly profits that depend only on opportunity cost of bank lending IOR (interest on reserves). If CBDC is available, it provides access to a perfectly safe deposit account and acts as a competitor for bank deposits at commercial banks. This can let banks to improve their services by offering cheaper and/or better products but, on the other hand, may lead banks to invest in and give loan to riskier projects at higher rate, resulting in a less stable financial system. In fact, the introduction of CBDC could affect

[89] In Canada, cash is widely accepted although only about 10 percent of transactions in value terms are conducted with cash. In contrast, in Sweden, where network effects on cash are becoming a source of concern, cash use sands near 1 percent of transaction value.

[90] 63 central banks participated in the survey: - Argentina - Australia - Azerbaijan - Bangladesh - Belgium - Brazil - Cambodia - Canada - Cape Verde - Cayman Islands - China - Colombia - Curaçao & Sint Maarten - Cyprus - Dominican Republic - Ecuador - Egypt - Euro area (ECB) - France - Georgia - Germany - Hong Kong SAR - Hungary - India - Indonesia - Iraq - Israel - Italy - Jamaica - Japan - Jordan - Kazakhstan - Korea - Kosovo - Latvia - Malaysia - Montenegro - Morocco - Netherlands - Nigeria - Norway - Pakistan - Papua New Guinea - Philippines - Russia - Samoa - Saudi Arabia - Serbia - Singapore - Slovenia - Solomon Islands - South Africa - Spain - Sweden - Switzerland - Thailand - Tonga - Turkey - United Kingdom - United States - Uruguay - Vietnam - Zambia

[91] For example, some consumers avoid online purchases because of security and privacy concerns when providing their credit card information. Also, smaller merchants often avoid selling online because of card fees, especially for small-value transaction.

[92] It is important to underpin that bank accounts have an important part to play in the founding and expanding of business, making transactions more efficient, secure and transparent managing saving, especially in emerging economies.

financial stability and banking intermediation if it competes with bank deposits. For his traceability and protection from loss or theft nature, it is reasonable assume that some will prefer and adopt CBDC lead to a growth of deposit interest rate and a more complementary financial services to make them more attractive. In this way, higher interest rate reduces banks' interest margin and banks would attempt to increase lending rate, though at the cost of loan demand[93]. As you can see from figure D below, the introduction of CBDC leads to a reduction of quantity of deposit from D_1^* to D_2^*. Banks will react increasing the interest rate on deposits. Nevertheless, you can see that if banks have more market power in lending, they will protect better their profits by passing the deposit rate hike on to loan rates. Moreover, banks with little market power adjust more quantity, leading to a larger contraction in deposit and loan volume.

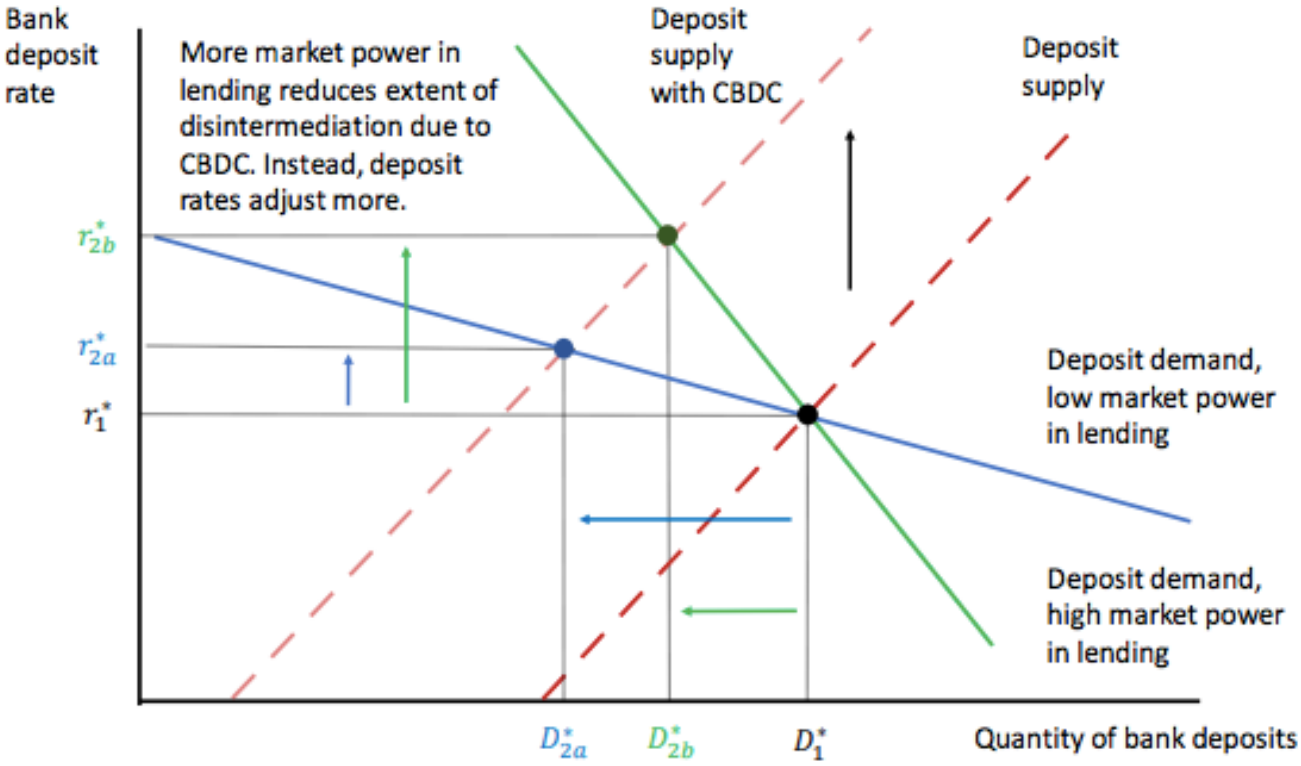

Figure D- Effects of CBDC and market power in lending (Source: IMF Staff)

To sum, commercial banks can earn some revenue when they issue bank deposits as direct consequence of financial inclusion and moreover can recapture a portion of seigniorage[94] if physical cash declines[95]. In fact, the sum of the value of bank notes in circulation and CBDC would likely be larger than the value of bank

[93] The net impact of CBDC depend also oh how the central banks introduce it, because if there will be an injection of CBDC via the sale of government bonds, this could lead to lower rates (Barrdear and Kumhof 2016).
[94] Seigniorage is defined as the revenue earned from the issue of money. According to Bheemaiah (2017) there are three sources of seigniorage for central banks in a fiat system. First, the difference in denomination of a given money and the production cost. Secondly, when commercial banks are in need of liquidity they reduce deposit holdings in the central banks, consequently reducing the interest on these deposits. Third, seigniorage stems from the proceeds of repurchase agreements made with commercial banks.
[95] Due to low interest rate, seigniorage has fallen since 2008 and if public opts to a private-cryptocurrencies, central banks seigniorage revenues could decrease further.

notes in circulation currently and this would increase seigniorage revenue.[96] There are two channels through which broad seigniorage value may change due to CBDC: the reduction of operational costs (related to printing, storage and transportation of banknotes and settlement costs) and CBDC may serve as a substitute for other non-deposit financial assets (shares in money market mutual funds). This latter effect would increase money in circulation and thereby broaden the overall seigniorage base. Seigniorage depends not only on the stock of currency in circulation but also from the difference between central bank assets and currency liabilities. Any CBDC-driven expansion of the balance sheet has a positive effect because most the funding cost equals the policy rate (i.e. the risk-free rate). Any asset that the central bank may buy from, lend to, or accept as collateral should have an expected yield above the expected risk-free rate over the investment horizon. As a CBDC-driven expansion of the balance sheet entails a corresponding decline of retail deposits and money market instruments, such increased central bank seigniorage corresponds to decreased seigniorage income at banks and money market issuers. This effect may be offset to some degree if CBDC were to lead to reduced demand for banknotes, which are non-interest bearing. The impact would depend on the remuneration of CBDC. In fact, in the case of a sufficiently low CBDC interest rate relative to the rates on bank reserves, banks could offer deposit rates above the CBDC rate, thereby avoiding the loss of deposits, and at the same time maintain the profitability of its funds. At the opposite extreme, a CBDC interest rate at the same level as that on bank reserves would force banks to raise the remuneration on their deposits above the CBDC rate. This, in addition to reducing their net interest margins, might lead to a reduction in the supply of credit and raise the cost thereof, likewise leading in all probability to a contraction in the banking sector's intermediation capacity. Actually, the cash's share in payment amount is decreasing and its decline continue to happen. But in a scenario where the future demand for CBDC match or exceed the existing demand for cash could increase the seigniorage. To sum, a central bank would need to accommodate demand for CBDC : flows into CBDC would drain the amount of reserves in the system in the same way as flows into banknotes and central bank deposits held by non-monetary counterparties (e.g. the treasury, foreign central banks or financial market infrastructure) currently do. To compensate all flows in and out and to keep the desired amount of reserve, in a corridor system, it will be necessary open market operations and , in a floor system, it will be necessary undertake additional liquidity-injecting OMOs only when CBDC inflows drained reserves to the point where they became scarce. Furthermore, they would have discretion in choosing the assets to accommodate the demand. Assets can be made up of outright holdings of any kind or collateralized lending to monetary counterparties on any terms and conditions. Subject to the overall supply of various types of asset and change

[96] Barrdear and Kumhof (2016) argue that interest-bearing CBDC would lead to a large increase in demand for central bank liabilities, which would lead to an increase in seigniorage, and, in turn, to larger residual transfers to the government. They also note that with such a large shift into CBDC, the central bank would need to hold more government bonds on its balance sheet. This increased demand for government bonds, other things being equal, would increase bond prices and lower associated bond interest rates, thus reducing government funding costs.

thereof, the additional duration, liquidity and credit risk stemming from accommodating the demand for CBDC is thus determined by the central bank itself, as in the case with banknotes.

Demand for CBDC may be volatile on a daily basis, as inflows and outflows result from payments between CBDC and non-CBDC holders. The quality of liquidity depends on the predictability and forecasting of daily flows in and out of CBDC. This leads to higher overall volatility depends on the correlations with other factors[97] and if forecasting in and out flow of CBDC become particularly difficult, central banks can be forced to operate through a floor system. At the same time, depending on the specific assets held to accommodate the issued CBDC, central banks would probably need to engage in various kind of maturity, liquidity and credit risk transformation. How these two forces balance out in terms of various interest rates across assets classes and maturities are likely to depend on each jurisdiction's specific operating environment. Also, since operating environments may change in the future, monetary policy cost-benefit analyzes related to CBDC may need to be revisited periodically. However, the CBDC interest rate would mark the floor on interest rate. No one with access to CBDC would lend at a rate below that offered by CBDC. That would break the current existence problem of the zero lower bound allowing bigger cuts in nominal rates, whenever it is necessary although there are already low rates. The problem refers to the difficulty of financial institutions to set negative remunerations on retail bank deposits, since in that case agents might withdraw their fund and save through the accumulation of banknotes. In fact, costs associated with banknote storage mean that these rates may be slightly below zero, but they cannot be arbitrarily negative. This is a limit for expansionary monetary policies in an environment of low interest rates, because can lead to a liquidity trap. Instead, in the hypothetical scenario of non-remunerated CBDC, the remuneration of commercial banks' reserve at central bank would continue to mark the floor for short-term interest rate in the interbank market and when the interest rate nears zero, the only possibility is to use unconventional policy tools, for example Quantitative Easing. Regarding this tool, it is used to inject liquidity in the economic system by purchasing assets from private sector with newly created central bank money. Actually, non-banks cannot hold electronic central bank so must use commercial banks to sell assets to the central bank. A universally accessible CBDC would remove this need of intermediation and QE could be carried out directly with non-bank participants. A central bank could increase the aggregate supply of CBDC in the economy by purchasing financial assets from non-bank private sector or from the banking sector and paying for these assets with newly created CBDC. The non-bank sells an asset, the bond, to the central bank, transferring the bond to the central bank. The central bank pays for this asset by issuing new CBDC, which is credited to the CBDC account of the non-bank. As you can see from figure E, the central balance sheet has expanded and for the non-bank private sector, one asset has been replaced by another and so the total quantity of assets has no changed.

[97] In the case of a corridor system, this may necessitate more frequent liquidity-injecting and liquidity-absorbing OMOs, higher reserve requirements with averaging provisions or wider tolerance bands around reserve targets to steer liquidity conditions.

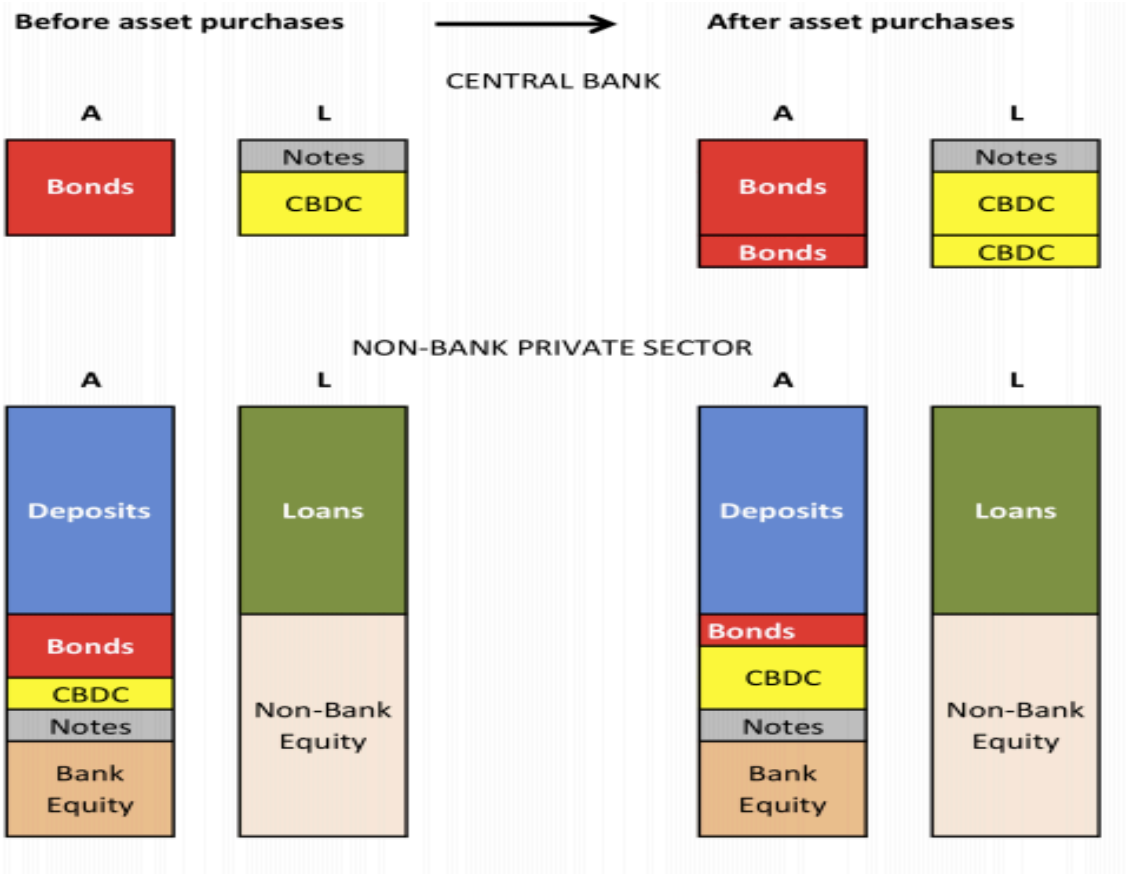

Figure E -Mechanism of asset purchases under CBDC system (Source: Bank of England)

When economy is in a liquidity trap[98], an alternative monetary policy could be "helicopter money" that would be more efficient to increase aggregate demand: each citizen receives a certain amount of cash for free and is believed to be a powerful instrument in deflationary scenario. The effect on the central bank's balance sheet is different: under QE central banks create reserves by purchasing bonds or other financial assets and the mechanism can be reversible, by contrast with helicopter money central banks give away the money created without increasing assets on their balance sheet, creating permanent effects. Because a CBDC would be universally accessible, it would give central banks an easy way of transferring money to the real economy without the need for the financial system as an intermediary. Moreover, the biggest problems that actually arise with this unconventional policy are:

1. Central banks pay interests on reserve that are effectively "free money" for the banks, since they would not have had to take any risk.
2. Due to the fact that reserves are remunerated, issuing helicopter money in the current system would incur an ongoing interest cost for the central bank and in turn for the government. This would mean that, from the perspective of government finances, helicopter money would have a similar cost to simply borrowing money through the markets by issuing bonds.

[98] When the central banks have reached the zero-lower bound, injecting liquidity in the economy to avoid recession is not useful.

3. It is desirable to avoid paying interest on the reserves issued through helicopter money and to differentiate interest-bearing and non-interest-bearing reserves. But this would complicate the reserves system.

Assuming that no interest would be paid on digital cash, the introduction of digital cash issued by the central bank would allow helicopter money to be implemented without creating these problems.

With regard to conventional policy, changes in the CBDC rate would affect agents' spending and savings decisions, either directly the remuneration of funds deposited at central bank, or indirectly through their effect on the remuneration of deposits at commercial banks. In turn, changes in banks' funding costs affect the interest rates at which banks lend to the real economy. In short, the remunerated CBDC scenario would afford the central bank greater control over the general financial conditions in the economy and, therefore, over aggregate demand.

After this analysis, it is clear that the impact of crypto-asset backed and issued by a central bank is positive on the overall financial system. Not only for the direct consequences on payment system, aggregate welfare and financial inclusion but also for new mechanism that facilitate the transmission of monetary policy. But it can happen only if the central banks work together, as they are actually doing, to find the optimum design and appropriate interest rate.