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Digital Euro and Crypto Currency

Supervisor Candidate
Prof. Riccardo Calcagno

Candidate
Giulio Bossi

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1. Abstract

Nowadays digitization is becoming a topic which is entering in every aspect of human life. From the industry sector to our daily routine, digitization makes process more efficient, more reliable, and faster. Also in the financial sector this revolution has becoming evident. The rate of innovation has quickened in the last decade and citizens show an increasing preference for digital payment. For this reason, the European Central Bank (ECB) has decided to settle a specific taskforce with the scope to discuss the introduction of a Central Bank Digital Currency (CBDC) in the Euro Area and its possible implications.

Our scope is to analyze the possible scenarios proposed by the ECB in which an emission of CBDC would be accurate and their related probabilities of occurrence. A second scope is to identify eventual implications of the CBDC in our society and in the economic system, obtaining as result a possible list of requirements and specification that would shape the Digital Euro. Hence, analyze pros and cons of the models proposed by the ECB, identifying a possible comprehensive solution.

During the work of this Thesis, will be also discussed the difference between a CBDC and a crypto currency (as Bitcoin) in terms of specification and pricing.

2. European Central Bank

2.1. History and Structure

The European Central Bank (ECB) is the major actor of the Euro system and of the European System of Central Banks (ESCB), being one of the most important mechanism of the European Union. The ECB directs monetary policy of the entire Eurozone with several instruments and defines the monetary objective of the EU.

The European Central Bank formally substituted the European Monetary Institute (EMI) on 1st June of 1998 by virtue of the treaty of Amsterdam. However, it exercised its entire power since 1st January in 1999, which is the day of introduction of the Euro. It is headquartered in Frankfurt, Germany.

It is important to notice that in terms of monetary policy ECB is responsible just for the countries that have adopted the Euro, thus not every country in the European Union. Countries which are under the direct influence of the Central Bank in Frankfurt are the following:

1. Spain
2. Germany
3. Belgium
4. Greece
5. France
6. Luxembourg
7. Austria
8. Slovakia
9. Lithuania
10. Finland
11. Portugal
12. Malta
13. Slovenia
14. Estonia
15. Latvia
16. Netherlands
17. Italy

18. Cipro
19. Ireland

Each governor of the national Central Bank is also a member of the Governing Council, the main decision-making body of the Euro System. In the Governing Council, beyond the nineteen members as representatives of national bank systems, there is the entire Executive Board, mind of the entire European Central Bank. The board is composed by six members, the President of the Bank, the Vice-President and four other members. They are appointed by the European Council for non-re-newable terms of eight years.
Overall, the Governing Council is composed by twenty-five members. Nowadays, the president of the Board is Christine Lagarde, and the Vice-President is Luis de Guindos. To complete the overview of the structure of the ECB it must be said that other two decision-making bodies exist: the General Council, which will continue to exist until every of EU will adopt the Euro, and a Supervisory Board.

2.2. Scope of ECB

In order to have a deeper understanding of all the present Thesis, even if a general idea of how the European Central Bank is composed is relevant, far more important is establishing the objectives of the ECB. As primary objective, as set out in the Treaty of the Functioning of European Union, ECB declares to pursue the price stability of the entire Eurozone (1). Though it is not strictly declared in any official document, it is worldwide recognized that ECB aims at maintaining inflation rates below, but close to 2%. This goal is basically shared by every Central Bank around the globe. It is common sense to avoid significant rise of the national prices, particularly for essential items as foods or gasoline. In fact, the inflation rate is managed not only to avoid a weakening process of the currency, but especially to prevent further burdens to face for families in the middle/low range of income. Anyway, it is also suggestable to not meet too low level of inflation (deflation), close to zero or negative, that would cause a rise in savings and consequentially a price decline, inducing a death cycle, bringing with it several defaults. In fact, if the inflation rate indicates a faint trend, households can expect that in the future prices will be lower

and have a greater utility in saving rather than invest or consume. Hence, the general idea of each Central Bank is that a two percent rate of inflation shows a wealthy economy, which is rising, but still not causing social-economical problems.

2.3. Monetary Policy

In a nutshell, the idea of the European Central Bank is establishing a monetary policy to induce a stability in the price of goods. The direct question that could rise in every mind is how the Central Bank could do that and which are the tools used by the Governing Council to handle the direction of the economy in the Eurozone.

There are several instruments that ECB could manage to influence the economy. However, the best-known are the interest rates that the Central Bank charges to all the bank system (commercial bank) across Europe. In particular, the Main Refinancing Operation rate, also called MRO rate, indicates the interest at which a bank can borrow money by the European Central Bank for one week. In Europe, this happens through several repo operations every week. Basically, commercial banks sell collateral assets (their securities) to the ECB, which loans money in exchange. By agreement between the two parties, at the end of the week, the borrower (the commercial bank) is forced to buy back its own security at a slighter higher price. However, the current situation presents some exceptions. In fact, MRO rate is currently equal to zero. Thus, the European Central Bank is basically borrowing money for free. In the table below, it is possible to find how MRO rate has changed since 2011 (second column).

2019	18 Sep.	−0.50	0.00
2016	16 Mar.	−0.40	0.00
2015	9 Dec.	−0.30	0.05
2014	10 Sep.	−0.20	0.05
	11 Jun.	−0.10	0.15
2013	13 Nov.	0.00	0.25
	8 May.	0.00	0.50
2012	11 Jul.	0.00	0.75
2011	14 Dec.	0.25	1.00
	9 Nov.	0.50	1.25

Figure 1: Trend of the three main monetary policy rates by the European Central Bank

Therefore, the MRO rate is a clear driver of the bulk of liquidity available to the banking system.

Though MRO is quite powerful, it is not the only rate directly controlled by the European Central Bank. The Marginal Lending Facility (MLF) rate is really similar to the MRO. It indicates an interest rate that a bank pays if it borrows from ECB overnight. It could be seen as a very short-term loan, which clearly exhibits higher value with respect to the MRO. Nowadays, MLF rate is set at 0.25%, showing a decreasing trend in the last ten years. The last rate that must be mentioned is the Deposit Facility Rate. It is probably the most discussed in the economy world given several consequences that has shown in the last years. As the name suggests, it is the interest rate that commercial banks get paid on their reserve, held by the European Central Bank. It could be quite surprising to discover that for the last seven years the Deposit Facility Rate has been negative, as can be seen in the previous Table (first column). Hence, commercial banks are paying the ECB to deposit their money on the ECB reserves. Even if it seems totally unlogic, negative interest rates have a reason behind them. The idea is to force banks not to hold on their deposit (reserves) and make those amounts of money available to firms or investors in the form of loans. This way of reasoning is just an example of how changes in the interest rates could induce changes in the behaviors of the main actors in the economic world. (2)

This set of three interest rates also determines the evolution of fundamental interbank market rate. It is possible to discuss an example taking as a reference the Eonia rate. Eonia stands for Euro Over Night Index Average. It indicates the interest rates at which commercial banks borrow money to other commercial banks, overnight. Thus, it can't be lower than the ECB deposit rate otherwise lenders would save money in reserves rather than lend money. On the other hand, the Eonia rate could not be higher than the MLF rate. In fact, a bank with liquidity demand would borrow from the ECB instead of from another bank. This is just an explanation of how the European Central Bank can affect with its own decision all the underlying market, affecting banks and all the investors.

It has to be kept in mind that open market operations consist also in a more medium-long term liquidity-providing action. The Longer Term Refinancing Operations (LTROs) can have a maintenance period from three months up to three years. In particular, in situation of crisis, LTROs and even the TRTROs, targeted operations that provide financing to specific credit institutions for periods up to four years, are fundamental to sustain the market giving favorable conditions to banks and stimulating lending to the real economy. Nowadays, it exists even a Pandemic Emergency LTRO to help banks through the outbreak of Covid-19 and the consequent collapse of the general economy.

The last operations described are usually called as Non-standard measures and they are totally traceable to the financial crisis begun in 2007. The famous expression of Mario Draghi, the present Prime Minister of Italy and former President of the ECB, "whatever it takes" shows how central banks in a period of Crisis have the duty to try every possible operation to boost the market. Central banks have even more powerful weapons with respect to the ones that have been described before. Instruments as the Quantitative Easing (QE) are used when open market operations are no longer effective. QE increases the money supply by purchasing assets with newly created reserves in a way to provide to the bank system more liquidity.

In conclusion, the European Central Bank has a portfolio of possible tools to utilize which influence interest rates in the market and therefore the easiness to lend money to the investors. Lowering interest rates is one of the primary objectives that a Central Bank should have during a crisis and with this set of tools this is possible. However, the introduction Digital Euro and the way which economic world is rapidly changing rise several questions on how the European Central Bank will face these new challenges and whether bank system paradigm would be ready to change.

3. Possible Scenarios to implement a CBDC

In the first section of the report released by the ECB (3), it is described a list of possible scenarios which could motivate the emission of Digital Euro. Overall, there are seven non-exclusive scenarios, five of them directly related to core central bank functions, while the last ones more relevant in a wider perspective of the objectives of EU. In the following we will describe these scenarios and discuss their likelihood of occurrence.

3.1. Digital Revolution

The digitalization and independence of the european economy can benefit from a digital form of central bank money available to citizen. (3)

ECB declares that digitalization of the economy in the financial sector could foster innovation in the broader economy. Moreover, payment service provider (PSP) could reduce costs making their business process more efficient and supervised intermediaries could develop end-user solutions accessible to citizens.

Hence, the first requirement that the Digital Euro should satisfy would be to enhance digital efficiency (R1). The idea consists of keeping pace with the state-of-art technology to satisfy as much as possible new requests from the market.

Even if the correlation between a digitalization in payment system with the entire industrial sector is not clear, it could be substantially confirmed that with a pan European End-user solution PSP could foster and enhance their gateways in order to be more efficient and reduce costs. In fact, it could preserve European autonomy and could make Europe as a leading player in the strategic sector of the retail payments.

3.2. Role of Cash as a means of payment decreases significantly.

ECB fears that, if the reduction of circulating cash will decrease beyond a certain level, the sustainability of the cash infrastructure could be endangered. The Digital Euro could be seen an additional form of means of payment with several

characteristics that are attractive to the consumers: cheap to use, secure, risk-free, easy to use and efficient. (3)

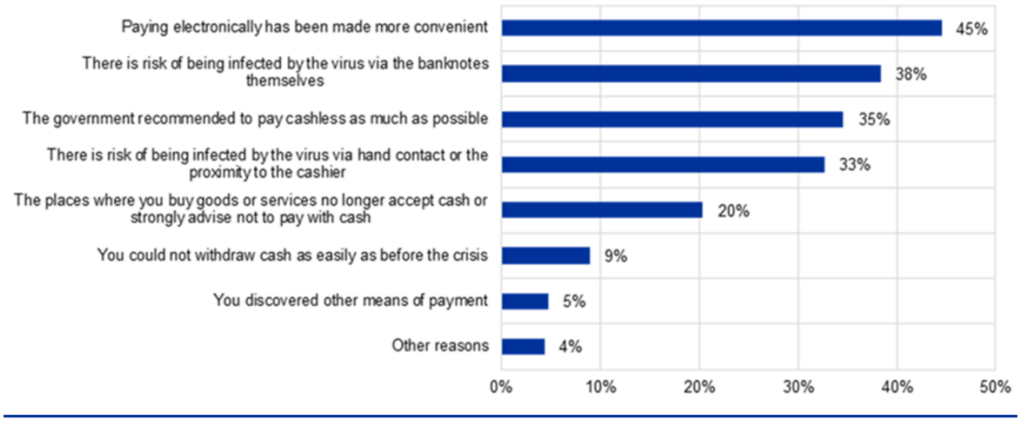
Really interesting is to analyze data that explore the probability of occurrence of such scenario in the Eurozone. Actually, this process is already happening. These data are obviously affected by the present pandemic situation. However, it turns out that the insurgence of Covid-19 has just accelerated a process that was already trending in the last ten years.

In particular, the ECB, reports that the usage of cash in 2020 has dropped by 20% and that around 40% of the citizens of the Eurozone were using cash less frequently. This is also reported in the Financial Times paper's by Claer Barret "Clash use plunges during pandemic" (4), where she reports an impressive 30% percent of reduction in the United Kingdom regarding the usage of cash, doubling the decrease of the previous years (around 15% each year). More impressive is probably the fact that less than a fifth of payments last year were made in cash.

The European Central Bank also reports a clear reduction of the banknotes flow across all the Eurozone.

It is fair to say that this is highly correlated to the outbreak of COVID-19 but the surveys of the ECB have reported some interesting facts (5). Respondents of the surveys, once asked which are the main reasons for changing payments behavior during the pandemic, have indicated that paying electronically has become more convenient nowadays as the first reason of the shift in their behavior. The risk of being infected by the virus is "only" the second reason of the slump of cash during the last years. Moreover, there are reasons as being compliant with government policies (recommending pay cashless as much as possible), difficulty in withdrawing money and not acceptance of cash (or strongly not advise) to buy goods in several places.

These are clearly real proofs that the decline of cash is not totally correlated with pandemic. In fact, it seems to be more related with a shift of the behavior of consumers that could be endless and lead the role of cash to the extinction. Hence, the likelihood of this scenario appears high.



Source: ECB.

Figure 2: Reason for Changing behavior in the pandemic situation.

In addition, if we analyze this issue from a socio-demographic perspective, youngers are less attracted by cash as a means of payment, underling the fact that this trend will only increase in the next future. In the range of age between twenty-five to thirty-nine years, only twenty-two percent of people have preference for cash.

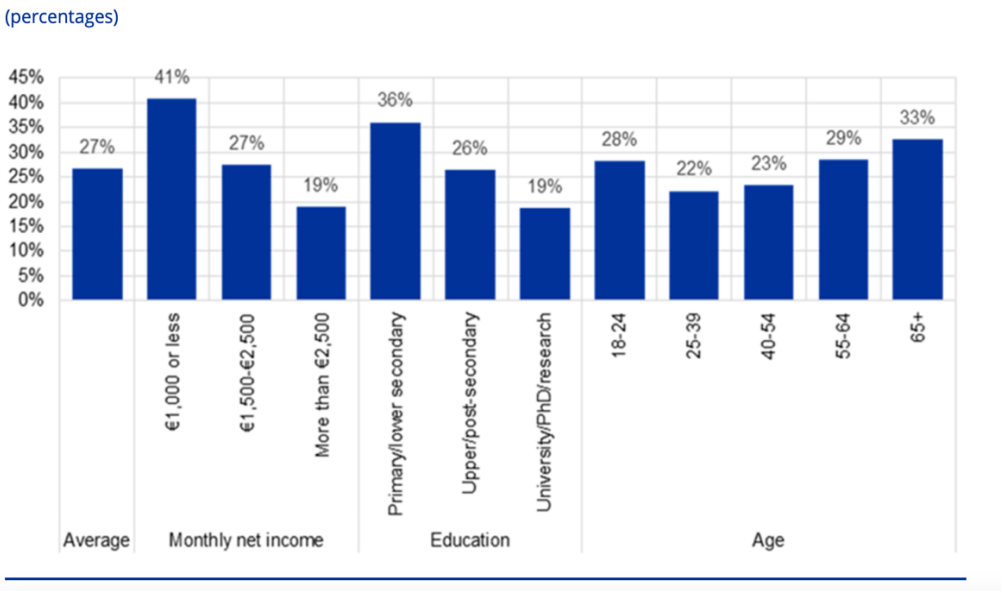


Figure 3: Share of respondents reporting a preference for cash, by socio-demographic group. Source: De Nederlandshe Bank and the Dutch Payment Association and Deutsche Bundesbank.

Fabio Panetta, member of the Executive Board of the ECB, states that, even if the decrease of cash is unavoidable, cash will not completely disappear. In fact, the volume of cash will remain stable. During the pandemic, there has been a huge demand for euro banknotes over the past years: an increase of 190billion of Euro, or 550 per capita. There was an increase of 4 to 8 per cent with respect to what was expected.

This is basically a paradox; however, the explanation is clear. During a period of crisis, consumers are usually risk adverse and cash is a risk-free asset. There is also a tendency to hold liquid assets and cash is the most accurate asset in this case. Hence, citizens are basically reinforcing the role of cash as a store of value rather than means of payment. Data support this thesis. In Euro Zone just 20%-22% of banknotes are used as transactions with respect to the scope of storing value, which represents at least the 30% (even 50% in some report) of the total amount of banknotes in circulation.

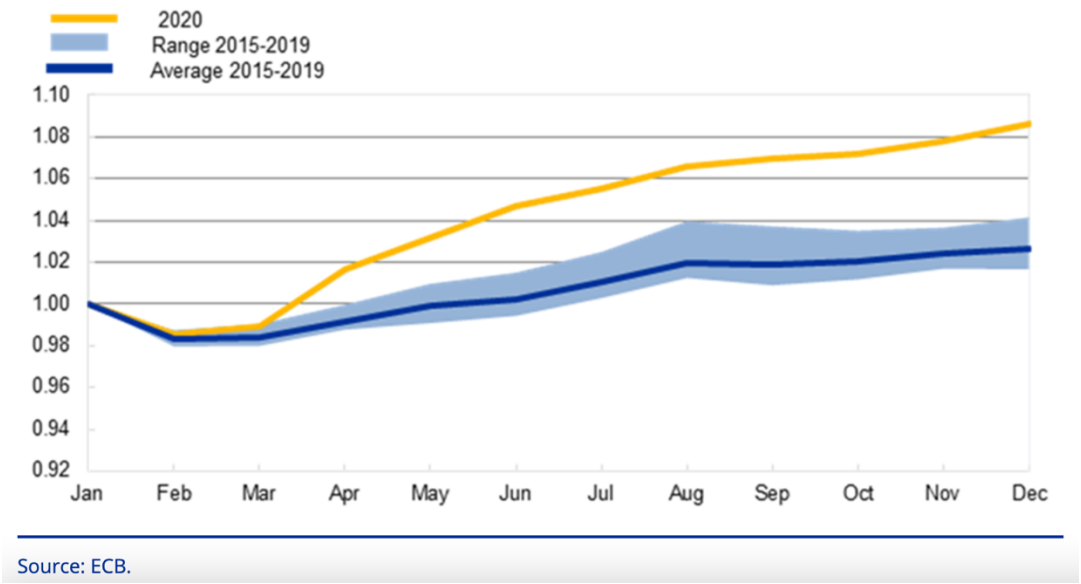


Figure 4: Total Value of banknotes circulation in 2020 compared with the previous five years.

It is also important to consider the fact that cash has an important feature with respect to the digital payments: inclusivity. It allows almost everyone, elderly people,

or people with lower level of education, to have transactions and to check their level of liquidity.

In conclusion, Fabio Panetta forecasts that cash will survive the digital revolution and data seem to support his thesis. On the other hand, the taskforce of the ECB has observed decline of cash as a means of payment and this trend is extremely increasing.

3.3. New Competitors

Wide acceptance of a means of payment or store of value not denominated in euro could weaken or even impair the transmission of monetary policy in the Euro area. This could happen in two different ways. On one hand, other Central Banks are evaluating, simultaneously to the ECB, the possibility to issue their own CBDC. This could cause strong currency substitution and impact foreign exchange rate, increasing consequently Forex risk. On the other hand, private actors are developing their means of payment (such as "global stable coins") that could become extremely diffused in the next period.

The real emergency could be a weakening of the monetary policy of the ECB, not being able to control volume of liquidity in the zone, fundamental to have an influence on the inflation.

The phenomenon of CBDC has already blown out worldwide. China is the furthest along this route, having initiated a pilot project for the introduction of Digital Yuan. The Digital Currency Electronic Payment (DC/EP) is backed by China's Central Bank. Basically, banks are required to convert a part of their yuan in digital form and distribute them among citizens. This would enable governments to have a better track of the flow of money and takes more accurate decisions regarding financial situations. Furthermore, a digital yuan will lead China's unbanked population towards the mainstream economy. Finally, as last benefit, Digital Yuan could foster the international status of the Renminbi (Yuan), emerging in the discussion of replacing the dollar in the international trade.

Russia does not fall behind. In October 2017, Russia' s president Vladimir Putin has declared that his country would issue Crypto-ruble, defined by him as a state sponsored "cryptocurrency". The testing has started at the end of 2021 within

several banks and to be in the hands of Russians during 2022. Unfortunately, it is commonly believed that one of the main reasons of this impressive investment around the digital currency in Russia is strictly related to the possibility to make transactions with counterparties all over the world, without the heavy sanctions currently imposed on the country by international communities.

Given this infrastructure already established in leading role countries around the word, the European Central Bank appears to be frightened by insurgence of different paradigms of Central Bank with respect to its own and is trying to keep track of all the innovations across the globe.

In addition to that the emerging word of stable coins is possibly more scaring in the long period. Stable coins are a class of crypto currencies. However, they are backed by reserve assets, with the attempt to resolve the problem of the huge volatility of the standard crypto. This idea has originated the seed for a possible currency substitution. In fact, a crypto currency with a volatility-free stable valuation has a clear purchasing power and becomes comfortable to use even in daily transactions. Theoretically, if the crypto has a low inflation, consumers could be incentivized to spend the token rather than saving it. In this scenario, one doubt could be what are the collaterals of this kind of currencies. Up to now, three types of possible collaterals have been evaluated: Fiat-collateralized stable coins, Crypto-collateralized stable coins, and non-collateralized stable coins, which include a working mechanism (as an algorithm) to control the price stability. In particular, the two most renowned stable coins, Tether and USDC, both backed by the dollar, have already a huge capitalization in the market. It is extremely impressive to note that Tether has a market share of 64 billion of dollar, being tripled in the last year.

Given all the above, scenario 3 seems to be likely, and it is probable to forecast that the European Central Bank and all the other central banks around the world will face this issue soon, with their strongest weapon, the digital currency.

3.4. Monetary Policy

Euro system could conclude that the issuance of a Digital Euro is necessary or beneficial from a monetary perspective.

In this scenario, the task force supposes the possibility to issue a kind of CBDC remunerated through an interest rate. Therefore, theoretically, ECB could have an instrument to directly control the consumption and investment choices of consumers. Notice that the use of the word “control” regarding choices of consumption it is maybe too arrogant. However, the existence of an inverse relationship between rates and level of investments is one of the pillars of the macroeconomics. Nevertheless, there is not empirical evidence in case where rates are applied directly to the individual holdings, as it could be in the case of CBDC. The possibility to settle an interest rate on the Digital Euro will be discussed later in detail. In any case, Report (3) does not discuss a clear correlation between a more substantial monetary policy and the issuance of digital currency. It seems realistic to suppose that coexistence of cash with the CBDC would lower the effect of a revolution in the monetary policy. Hence, this scenario should be analyzed after having depicted a clear picture of the possible prototypes of CBDC in the Eurozone.

3.5. Force Majeure

The Digital Euro could mitigate the probability that a cyber incident, natural disaster, pandemic, or other extreme events could hinder the provision of payment services.

In the "systemic cyber risk” report (6) it has been evaluated that the frequency and impact of cyber incidents have increased in the last years. In particular, the financial sector has been one of the predominant targets for cybercriminals looking for financial gains. The estimation of total loss caused by cyber-attacks, although difficult to estimate, ranges from USD 45 billion to USD 654 billion for the global economy in 2018. Failures of card service providers or bank back up system have a huge effect on millions of consumers. Hence, cyber risk could be considered as a systemic risk, defined as a disruption in the financial system, causing potentially huge consequences in the real economy. In this scenario it would be fundamental the degree of clarity about the losses. Otherwise, it could rise a huge loss of confidence

in investors, which could endanger the financial system and all the industrial sectors.
Accordingly, European Central Bank and the task force claim that the evolution of Digital Euro could improve the overall resilience (ability to carry out its scope by adapting to cyber threats) of the payment system. The Digital Euro, made available through resilient channels, could be an alternative of other payment services, surviving major events.
It is important to mention other types of force majeures. For instance, during the Covid-19 pandemic some people have been afraid using cash, considering money a medium to be infected. This scenario, a natural disaster, or other extreme events should be considered by the ECB.
Eventually, the adaptation of a digital euro by the European Central Bank would reinforce the degree of resilience of the infrastructure on which hundreds of millions of people rely.

3.6. Euro Relevance

The international role of the euro becomes a Euro system Objective.
This is the first scenario more related to a wider objective of the European Union rather than the specific scope of the European Central Bank.
This scenario is particularly relevant for cross currency payments. The volume of cross currency payments, as reported by the Bank of America (7), is escalating for several reasons: globalization, international e-commerce becoming widespread, mobility of people and the increase of outsourcing in emerging countries. Consequentially, foreign exchange stability becomes crucial for all the industrial sectors, not just for the financial one. Nevertheless, firms are not still considering volatility of the Forex index as a priority risk. However, ECB does. It is not a coincidence that in the G20 of the last year one of the discussed topics was the likelihood to enhance cross border payments and resolving frictions in the existing system.
The Digital Euro would go towards that direction, reinforcing the status of the Euro and lowering the risk of disadvantageous foreign exchange rate. Furthermore, the possibility to grant Digital Euro outside the euro area, to non-euro area resident,

would improve all the payment scheme due to a global market. In conclusion, it seems possible to improve operability dealing in different currencies.

3.7. Cost and Ecological footprint

Euro system decides to proactively support improvements in the overall costs and ecological footprint of the monetary and payment systems.

To understand the impact of the ecological footprint of cash, it is useful to analyze the outcome of the paper "Life Cycle Assessment of cash payments in the Netherlands" by Randall Hanegraaf and Atakan Larcin (8). They have used the LCA approach to determine the impact on the environment and on climate change caused by cash and coins. The five analyzed subsystems are: the production of coins, the production of cash, the operation phase, the end of life of banknotes and the end of life of coins. The impact category more weighted was the climate change factor and it has been used to obtain the environmental impact of the payment system, measured in eco points. The results show 2.42 MPt. Moreover, data show 19millions kg of CO2 equivalent related to coins.

In the LCA, as universally acknowledged, the real important results are the comparison between the different stages of the process, to obtain clear evidence of which is the dominant phase. Hence, the LCA has not as an outcome an absolute value but rather a set of values to be compared. According to (8), the operation phase has the most dominant impact on the environment, contributing to 64% of the entire process. In addition, it seems to be the most relevant one also if it is considered the effect on the climate change. What are the main activities contained in the "operation phase"? In (8) the two most mentioned ones are the energy usage of ATMs and the transportation of banknotes and coins. These results show that the payment system, as the majority of industrial sectors, is heavily affected by the indirect consumption of carbon-fossil fuel or gas. Potentially, this could be overcome in the next years, thanks to the rise of renewable energy. However, the reduction of carbon emission and of the consumption of energy (green or carbon dependent) in

the case most consumers would use the Digital Euro or other forms of CBDC would be much larger.

Some concerns have been arisen about the environmental impact of the Digital Euro, by equate it to the one produced by the crypto currencies. However, it is important to not make confusion. The environmental impact of crypto currency is huge, probably greater respect to physical cash, but this should not be the case in the world of Central Bank Digital Currency. The negative impact of Crypto is caused by the enormous amount of energy required for mining and the competitiveness of Proof of Work (see Chapter 6). As stated by the Cambridge Bitcoin Electronic Consumption, only Bitcoin uses 122.87 TW/hr of electricity every year, more than countries like Netherlands or Argentina (9). Even if these figures are scaring, CBDC should likely not require a Proof of Work system and surely would not encourage a "Block-rewarding" approach. As will be discussed in detail along this Thesis, even if it is still unclear which kind of approach would be chosen by central banks, P2P will not be an option in a centralized system. Hence, mining activity will drastically reduce, and the environmental impact would be tinier or inexistent.

It should also be considered the economic impact on the cash system. In some regions where the decline of cash was unavoidable and very fast, suddenly banks faced an increase in the percentage of fixed costs, causing an increase in the unit cost operation. Banks have been concerned about this issue, understanding that the fixed costs are linked with human labor (distribution, maintenance, processing) which is also showing an upward trend in some countries.

In the last years some solutions have been proposed (10). Applying an intense lean approach in the bank system is one of them. Concept as "maximize output and reduce waste" eliminating repeated steps in the replenishment process, primarily in cash distribution centers, have shown some results. In the perspective of a lean approach also the usage of some software applications regarding cash forecasting and inventory management could be applied. A second approach could be a re-design of a more efficient network, including to balance out branches and ATMs. In fact, ATMs cause high level of costs due to cash transport, IT hardware and maintenance. A third and last approach is optimizing cash distribution through shared utilities.

Pooling resources in a joint network can ease the economic burden of the operating system behind cash.

Even if all these solutions can be reliable in the short term, if the decline of cash will continue, probably they would not be sustainable. In this scenario, the issuance of a Digital Euro by the European Central Bank could be a rescue anchor for the whole bank system. It would also be a sort of competitive advantage with respect to banks operating in the market without a circulating CBDC.

Table 1: Identifying the likelihood of each scenario evaluated in the European Central Bank Report with a synthetic explanation

Scenario	Probability	Reasons
1	Medium	Digitalization in the economy is already occurring, even before the introduction of digital currency. Even if it is not clear the correlation between the innovation in the industrial sector and the CBDCs, it is plausible to say that a digital currency could foster efficiency in the market. PSPs could enhance their services.
2	Very High	The decrease of cash as a means of payment seems unstoppable. The data previously shown prove that younger people prefer other ways of payment and that new services are gaining shares in the panorama of payment services. Cash will probably remain as a value asset.
3	Very High	China and Russia have already established pilot projects, with expected results in the close future. The rise of stable coins is still in a primordial phase. However, this new financial instrument seems to overcome several problems of its "cousin", excessive volatility in the spotlight, and there are not still clear disadvantages.
4	Low	The possibility to have a remunerated currency seem unfeasible because too far from the concept of banknotes. It would probably cause a general dissent by the citizens of the Eurozone.
5	Medium	It is possible to correlate the increase of resilience in the infrastructure of the payment system, avoiding huge cyber threats. However, there exists several

		alternatives to reinforce the safety of the system and have a back-up plan in a case of "major risk".
6	Medium	Even if Foreign Exchange rates are becoming more relevant in the last years, it seems still a topic that does not concern most big firms around the globe. In any case, improve operability of the cross-currency payment system is a clear objective of several central banks.
7	High	The ecological footprint of cash is clearly dominant in the operation phase, which is exactly where you gain most using CBDCs. Avoiding ATMs and transportation of money is a further step towards a greener world. In addition, the rising of fixed costs, due to the reduction of circulating money, is an issue that commercial banks must face. It is possible to suppose that in a far future banks should reinvent themselves in a different paradigm with less branches and a more digitalized system, maybe based on a digital currency.

4. Implications after Issuance of a Digital Euro

In this chapter some possible consequences related to the issuance of a form of Digital Euro will be analyzed. This topic is particularly important because in this way it is possible to depict a list of requirements to face probable negative aspects of the Central Bank Digital Currency's issuance.

As in the previous chapter, we will list a set of potential negative effects and their implied requirements, referring to the study performed by the European Central Bank and its task force. (3) The ECB has found six remarkable implications that should be studied in detail to be prepared in a short-term future.

4.1. Negative Effect on Monetary Policy

Emission of a Digital Euro could affect the transmission of monetary policy and have a negative impact on financial stability.

The risk is that, depending on the actual implementation of the Digital Euro, people could be induced to transform their bank deposits in holdings of CBDC. Hence, Central Bank liabilities would increase simultaneously to a sudden decrease of bank deposits. This is a real concern for the general economy. Less deposits for a bank mean an increase in the funding costs and higher interest rates on loans to sustain the bank business. Finally, a reduction in the volume of credit would be the outcome, affecting all the industrial sectors.

How will banks react to this problem? Firstly, they could try to pursue a customer-oriented policy increasing remuneration on deposits or through bundling services in a way to be more attractive and competitive with a digital currency. If this first option is not sufficient, banks could always consider replacing lost deposit funding with Central Bank borrowing. However, as shown before, banks need collaterals to sustain a repo operation with the European Central Bank. If MROs or lending overnight would become more common, there will be an increase in the demand of collaterals which might ultimately have an impact on market interest rates for safe assets. Furthermore, the Central Bank would be more exposed increasing financing to commercial banks. Consequently, the level of risk will substantially grow. A third option would be substituting deposit funding with more expensive capital market-based funding.

The negative effect of a bank disintermediation could not only damage the banking sector but the financial stability in general. In fact, if the bank should face a rise in funding cost and consequentially a decrease in the volume of credit, it could be prevented in insuring a correct level of investment and consumption in the society. Furthermore, banks may decide to recover higher profits taking greater risks, becoming less safe than before (more likely to default). Even worse is the fact that losing funds means having less information about clients, impairing the capability to have a clear risk assessment capacity. Many of these possible consequences lead to an increase in the riskiness of the bank's balance sheets, a clear sign of financial instability.

Moreover, this situation could worsen in a period of crisis. It is well-known that liquid assets as money (banknotes) are really preferred when there is general distrust in the banking sector. In a case where operations to withdraw money would result easier for holders of Digital Euro rather than for owner of commercial bank deposits, the scenario could become dangerous. The likelihood and the severity of a bank run becomes concrete, and all the financial activities could be hampered.

These issues show how it is relevant to discuss and forecast possible implications related to the issuance of the Digital Euro in a way to be prepared in case these scenarios occur. This is extremely important because it could help in the design of the Central Bank Digital Currencies. A first important point to take into consideration is whether the Digital Euro should be accessible by household and firms directly or through intermediaries, maybe banks themselves. This is directly related with the issue of financial stability because it could imply a different role for the bank system in the economy and a different degree of responsibility for the Central Bank. A second feature to be considered is whether CDBC should be remunerated or not. This will be discussed later in deep details. However, the possibility to have an interest rate on the holding of the Digital Euro is likely and could be an applicable solution (11). A third doubt is whether the new Central Bank currency should be limited for a singular individual in terms of holdings or unlimited.

These characteristics will shape the Digital Euro and would have a direct consequence on the above-mentioned problems.

Given the risk previously described, it is not suggestable for the Digital Euro to attract very large investment inflows. In fact, a huge shift on the new digital currency implies lower commercial bank deposit funding and with a domino effect all the issues described before. On the other hand, individual holdings of Digital Euro could not be too low. The idea of the CBDC is eventually the possibility to have a currency which is competitive and attractive with respect to other alternative instruments.

In conclusion, the task force has set a requirement which a Digital Euro should satisfy. Requirement number eight state that European Central Bank should "be able to control the amount of Digital Euro in circulation". This would probably be one of the most crucial and challenging aspect of all the new concept of a digital currency.

4.2. Risk exposure of ECB

The Digital Euro could impact the profitability and risk-taking of ECB.

It is relevant to state that in general issuance of Euro is profitable. In fact, there is a gap between the remuneration of the asset belonging to the ECB with respect to the interest rate applied to Central Bank liabilities (in the case of banknotes the rate is zero). This system normally generates seigniorage income. However, it is not clear if this is the case also with the issuance of Digital Euro. The first important feature to analyze is whether the birth of the new currency could cause an increase in the balance sheet and consequently an increase of risk. It is fair to state that Digital Euro will substitute standard banknotes, thus not causing a considerable increase in the balance sheet; at the same time, if non-euro area residents would shift their portfolios into CBDCs it will cause an enlargement in the balance sheet. This implies that the European Central Bank would need to acquire assets to be held against the Digital Euro (collaterals). There are other features to be discussed to have a complete view of the impact on the profitability of the Central Bank. As previously said, the Digital Euro could be remunerated, not being risk-free, and potentially could affect the level of seigniorage income. Furthermore, the provision of digital cash (as for standard banknotes) is not free but brings with it some costs. Finally, the European Central Bank should face the problem of bank disintermediation and the

related “bank runs” issue. It is plausible that the ECB might need to lend Longer Term Refinancing Operations (LTROs) to banks in a situation of crisis. At this point, the gap between the rate of LTROs and the level of remuneration established for the Digital Euro would be crucial to have a clear idea of the seigniorage income for the ECB and its related profitability.

In addition, the European Central Bank should become a sort of operator on the retail payment system. In a case of IT malfunctions or unauthorized payment transactions someone the question could be risen regarding who is responsible for. Supposing also the existence of a payment service provider, it is reasonable to say that the PSP is acting on behalf of the Central Bank, being impossible to exclude an involvement in the direct responsibility and consequent damages.

These issues are all relevant, but it should be bear in mind that end users are likely to expect the Digital Euro to be free of charge. Hence, it will be crucial to depict the relationship between the involved third-party service providers and the ECB and to understand whether euro system would be able to impose fees to recover some costs.

Finally, even if European Central Bank has not as a primary policy objective profitability (rather price stability), an enhancement in the risk management would be necessary to face these new challenges and a probable fall in the profitability.

4.3. Reputation of ECB

The Digital Euro could affect the image of the European Central Bank in terms of reputation.

Many citizens could not understand the utility of this migration towards a digital currency. Besides an initial diffidence, people would need to know the clear benefit of this project, justifying the amount of costs related to the project. In addition, several factors could mine the general reputation of the ECB. A possible delay with respect to the announced implementation date would be not only a loss of time but also a loss around the confidence on this project. On the same level, problems with the IT infrastructure (unstable, not resilient), or a regulatory framework which is not working (encouraging criminal activity as money laundering) would be highly damaging for the reputational of the European Central Bank. Hence, the task force

has listed two fundamental requirements. Firstly, cooperation with market participants to benefit of the best practices in IT project management. In this optic, taking advantage of some supervised intermediaries, which already have in place some best practices seem the most reasonable choice for the Central Bank. They could leverage customer facing services and avoid duplication. Secondly, compliance with the regulatory framework. The feasibility and the perception of having a "clean" system is crucial to establish a new digital currency as the Digital Euro.

4.4. Retail Payments

Issuance of CBDCs could affect the efficiency on retail payments.

The Digital Euro would affect in particular the operation of the payment services providers. It is important for the Central Bank to not expel from the market possible alternatives having the same purpose. Its effort should be limited to ensure the effectiveness of the Digital Euro and its efficiency and usability. In fact, the European Central Bank does not want to discourage private market-led solutions for efficient retail payments in the Euro zone.

This is another field where the role of supervised intermediaries will be relevant and would be accessible to every segment of the population, being nondiscriminatory. In fact, one of the aspects to which the ECB pays more attention is to not generate financial exclusion, provoking inequality between citizens.

On a more technical framework, the Digital Euro could use existing pan-European payment solutions to align and make more homogenous a world with many different solutions. In fact, in recent years, significant improvements have been made to guarantee a safe, efficient, and integrated european payments market, especially thanks to the introduction of the Single Euro Payment Area (SEPA). However, this has been more a process happening in the back-end infrastructure not being translated into a similar progress at the "front-end". The current situation remains fragmented with no clear unique solution emerging for a homogenous payment service. The ECB has always declared full support to initiatives that lead towards a pan-European solution for point-of-sale and online payments. It could be speculated that the issuance of Digital Euro could boost towards this direction, integrating different solutions to a unique competitive European solution.

Following this approach, the emerging requirements are: “safety and efficiency in the fulfillment of the Euro System goals” and “easy accessibility throughout the Euro Area” (3). In particular, the second one underlines the need to have standardized front-end solutions in the entire Euro zone. Notice that it should be easy to be accessed by everyone, avoiding financial exclusion and ensuring an equal treatment for all the European citizens.

4.5. Cross-Border Effects

The Digital Euro could have several effects on the cross-border use of the Euro.
The first topic that should be discussed is something already mentioned before: if non-euro residents would decide to heavily use CBDCs in their portfolio it is likely that the quantity of circulating euro will rise, implying an increase in the size of balance sheet of the European Central Bank. Thus, the level of risk by Central Bank would increase, holding more collaterals against Digital Euro.
In addition, one should not forget how much it is important the strength of the currency in a globalized world as the present one. Paradoxically an enhancement of European currency could strengthen the Euro exchange rate and endanger the competitiveness of European firms. This paradox is just one of the proofs of the statement that a currency should “be strong but not too strong”. In fact, in a connected world like the present one, the equilibrium among currencies is fundamental to maintain a fair competitiveness around the globe.
The last topic leads to another important factor which should be taken into consideration. If the Digital Euro would not have constraints regarding its availability worldwide, it is likely that a currency substitution occurs in some third-world countries. In particular, it would penalize countries with weak economics, maybe with huge inflation, lowering even more monetary policies in those areas. A “euroization” is hugely seen by every expert as a scenario to be avoided (3). This would significantly impair monetary policy sovereignty in affected economies. Furthermore, it could provoke a sort of political risk, being the vehicle for a general “annoyance” towards the European economy. It should also be considered if it is ethical to build an instrument which could entail financial instability in poor countries.

Other two effects related with the usage of the Digital euro in non-euro area are remarkable. Firstly, spillover effects, as stock market crisis, earthquakes, or other major risks would be amplified because of a more interconnected economy. Hence, the Euro system will be affected by an increase in its riskiness. Secondly, the Digital Euro might potentially facilitate international criminal activities. This issue really depends on the degree of control that will be applied around this new type of currency.

Overall, it is possible to conclude that the Digital Euro should consider specific conditions regarding the accessibility and usability by non-euro area residents. To have a balance in the capital flows, stabilize foreign exchange rate and ensure safety for all citizens is exactly what is required by a currency, despite being digital. A conditional use by non-euro area residents (R13) seems unavoidable.

4.6. Cyber Attacks

A digital Euro may attract Cyber Attacks.

This last implication can be seen with two different approaches. On one side, a digital currency could boost a major attention to the cyber risk and become an incentive for a further development to a more resilient system. On the other hand, hackers and their cyber-attacks would be captivated by a new form of digital currency in order to profit from fraud, extortion, and data exfiltration. This has also consequence for point 3, the reputation of the ECB, and could endanger the value of the Euro itself. The integrity and the confidentiality of the information that is processed are crucial to gain trust by citizens and to push the usage of Digital Euro. Requirement fourteen (14) states eventually the necessity of a cyber resilient system.

Scenario-specific requirements	R1: Enhanced digital efficiency (if launched to support digitalisation): The digital euro should keep pace with state-of-the-art technology at all times in order to best address the needs of the market as regards, among other attributes, usability, convenience, speed, cost efficiency and programmability. It should be made available through standard interoperable front-end solutions throughout the entire euro area and should be interoperable with private payment solutions.
	R2: Cash-like features (if aiming to tackle a decline in the acceptance of cash): To match the key distinctive features of cash, a digital euro aiming to tackle a decline in the acceptance of cash should permit offline payments. Moreover, a digital euro should be easy for vulnerable groups to use, free of charge for basic use by payers and should protect privacy. It should have a strong European branding.
	R3: Competitive features (if introduced to limit the uptake of forms of money that are not denominated in euro and/or not appropriately supervised): The digital euro should have features which are at the technological frontier. It should offer the basis for providing functionalities that are at least as attractive as those of the payment solutions available in foreign currencies or through unregulated entities.
	R4: Monetary policy option: If considered to be a tool for improving the transmission of monetary policy, the digital euro should be remunerated at interest rate(s) that the central bank can modify over time.
	R5: Back-up system: If aiming to improve the overall resilience of the payment system, the digital euro should be widely available and transacted via resilient channels that are separate from those of other payment services and can withstand extreme events.
	R6: International use (if introduced to increase the international role of the euro): The digital euro should be potentially accessible outside the euro area in a way that is consistent with the objectives of the Eurosystem and convenient to non-euro area residents.
	R7a: Cost saving (if launched for cost efficiency): The design of the digital euro should achieve a reduction in the cost of the current payments ecosystem.
	R7b: Environmentally friendly (if launched for environmental reasons): The design of the digital euro should be based on technological solutions that minimise its ecological footprint and improve that of the current payments ecosystem.

Figure 5: Scenario-specific requirements listed by the Report of the European central Bank.

General requirements	R8: Ability to control the amount of digital euro in circulation: The digital euro should be an attractive means of payment, but should be designed so as to avoid its use as a form of investment and the associated risk of large shifts from private money (for example bank deposits) to digital euro.
	R9: Cooperation with market participants: A project to introduce a digital euro should be carried out in line with best practices in IT project management. The digital euro should then be made available on an equal basis in all euro countries through supervised intermediaries, which could leverage their existing customer-facing services and avoid the costly duplication of processes.
	R10: Compliance with the regulatory framework: Although central bank liabilities are not subject to regulation and oversight, in issuing the digital euro the Eurosystem should still aim at complying with regulatory standards, including in the area of payments.
	R11: Safety and efficiency in the fulfilment of the Eurosystem's goals: The digital euro should be designed in a safe and efficient way. Its project and operating costs should be estimated and compared with the expected benefits, considering alternative solutions in any future scenario. The provision of non-core services should be left to supervised private entities.
	R12: Easy accessibility throughout the euro area. The digital euro should be made available through standardised front-end solutions throughout the entire euro area and should be interoperable with private payment solutions. It should be easily accessible by anyone, including citizens who currently do not participate in the financial system (for example, those who do not have an account at a commercial bank), and should be easy to use. The digital euro would need to co-exist with cash.

	R13: Conditional use by non-euro area residents: The design of the digital euro should include specific conditions for access and use by non-euro area residents, to ensure that it does not contribute to excessively volatile capital flows or exchange rates. Such conditions could take the form, for instance, of limits or adequate remuneration policies for holdings of digital euro of non-euro area residents.
	R14: Cyber resilience: Digital euro services will need to be highly resilient to cyber threats and capable of providing a high level of protection to the financial ecosystem from cyberattacks. In the event of successful attacks, the recovery time should be short and the integrity of the data protected.

Figure 6: General requirement listed by the European Central bank after the discussion of the possible implications consequent to the issuance of the Digital Euro.

5. Specifications of a Digital Euro

The last section of the report of the European Central Bank (3) which will be studied in this Thesis concerns the main requirements that a Digital Euro should satisfy. This part is strongly related to the two previous sections. In fact, once listed all the requirements (scenario specific or general), the idea is now to set some functional specification that should comply to the principles listed before. In the Thesis, as before, we will try to make a further step, understanding the feasibility of some actions and pros and cons of some features.

There are ten specifications that are discussed by the ECB, one for each issue that can arise around the Digital Euro.

5.1. Access Model: direct or through supervised intermediaries?

A direct access means that European Central Bank should provide end-user facing services. Even if this is exactly what most of the crypto currencies do, it would be a total revolution for ECB, being totally outside of its core competencies in the field of customer identification or support in payments. Three possibilities could be taken into consideration. Firstly, the existence of a sort of settlement agent intermediation. In this scenario, intermediaries operate transactions on behalf of end users and provide storage facilities. In a second scenario, gatekeepers become the main actors to provide authentication and provide technical connectivity between users and payment system infrastructure. Finally, a direct model users access to the ledgers can not be intermediated.

There are several reasons to suppose that an indirect access model is preferable. In fact, the possibility to have leverage existing customer-facing services and to avoid challenges in areas which are not a core competence belonging to a central bank is vastly attractive. Furthermore, this will also enable to maintain a fair competitiveness in the market of payment service providers and supervised intermediaries. However, it is highly relevant that the safety and reliability of the digital currency is guaranteed independently of the intermediation type. It is not a case that (3) underlines the importance of preserving the nature of the Digital Euro as a Central Bank liability and avoiding any additional euro made by misconduct of an intermediary.

5.2. Privacy requirements

This is one of the most discussed topics in the economy world. On one hand, a great level of privacy is attractive for end users because it looks safer and more reliable. On the other hand, the European Central Bank should need some information regarding transactions to guarantee that public interest is preserved. In the current economy there exist a variety of means of payment with different degrees of privacy, from the total anonymous transactions using cash to payments where it is required documentary verification or monitoring actions by third parties.

Analyzing the current scenario, if the Digital Euro could be seen similar to the electronic payments, it seems unreasonable to guarantee a total anonymity. Regulations do no to allow electronic payments to be anonymous for reason of Anti Money Laundering (AML) and terrorism financing. Furthermore, in a Digital Euro situation, anonymity could not be promised in order to restrict the usage of digital currencies by their owners; for instance, it could be necessary to forbid ownership to non-euro residents to avoid a huge rise in capital flow or to limit Digital Euro as a form of investment to discourage bank disintermediation. In this model, users' holdings are recorded by a third party and transactions are authorized thanks to the ability of the third party to verify the identity of the payer. This is the approach adopted by the most important digital payment solutions around the globe.

An opposite solution could be the application of a knowledge-based approach. Thus, end users would not need to verify their identities, rather prove the knowledge of a piece of information as a code or a private key. Obviously, the proof must be verified. In the case of Digital Currencies ownership, validity is verified using cryptographic signatures, that can be seen by all the parties involved in the transactions. Anonymity, in this scenario, can be enabled.

However, approach to privacy can be selective. In some transactions an anonymous approach would be adapted while in the remaining ones the identity of the payer would be required. Large-value transaction will comply to the current regulation AML/CFT and will be inspected to analyze capital flow from non-euro area residents and to avoid Digital Euro to be used as an investment.

In any case operators of the infrastructure should guarantee data protection.

5.3. Discouraging large-scale use of a Digital Euro as an investment.

This requirement is probably the most concerning one. It would be the focus of the final chapter of this Thesis, being correlated with the problem of "bank runs" and the disintermediation of commercial banks. As already explained, the European Central bank should absolutely avoid a huge shift from commercial bank deposits into Digital Euro. The idea is to control the overall value of the new digital currency in circulation and to remain below an established threshold. This implies that users would be forced to have a threshold in their individual holdings of Digital Euro. Thus, respect to the specification 2 (privacy requirement), it seems even more unreasonable a total anonymity for the single users.

One of the options which has been investigated in the last years is capping the amount of CBDC per holder. In a case of deposit based CBDC, this should be technically trivial. Suppose a scenario in which a transfer of money implies an exceeding of established threshold; in this situation, the payment would simply be rejected. Even in a Distributed Ledger Technology situation, ECB does not see obstacles implementing caps in the wallets of CBDCs holders. However, some frictions could arise. There is the risk that a huge number of payments will be rejected for a reason that cannot be known in advance by the payer. Hence, reputation of this form of payment could be undermined and not be so effective. A possible solution could be the application of a "waterfall approach". The idea is to avoid that the payment could be rejected. On the contrary, any payment would be accepted, but it would trigger the automatic migration of the excess (level of CBDC holdings after a transaction – cap for a single holder) from a CBDC account/wallet to some other deposits (commercial bank deposits, investment fund). Obviously, it must be required to every owner of CBDC to establish such a "waterfall" account.

A second approach is a sort of an incentive scheme where Digital Euro are remunerated with some risk rates. The possibility to establish less attractive interest rates or services fees when the established threshold is overcome, represents a total breakthrough respect to banknotes or coins. The purpose is clear; to ensure that holdings amount above a certain level be less attractive than other forms of investment. In this scenario a tiered remuneration system can be a possible solution,

requiring appropriate thresholds set by categories of end users (companies, citizens, non-euro residents).

However, it is clear that giving unlimited holdings of Digital Euro could destabilize the general economy. In a period where government bonds evaluated AAA by rating agencies presents an interest rate of -0.5%, an unlimited access of Digital Euro could not be offered at a more attractive rate. Otherwise, the breakdown of the entire monetary policy and financial flows is unavoidable. This issue would not arise in territory where risk-free nominal interest rate is clearly positive. In those regions, an unconstrained access of Digital Euro (risk-free as banknotes) would become operable.

5.4. Restrictions on access to Digital Euro service.

As discussed before, the possibility to have an holdings limit is hugely studied because it could offer several solutions to some concerning issues. In this case, the feasibility to constraint holding of Digital Euro in certain jurisdictions has been put under the spotlight. Even if requirement 6 states the importance of the international use to be competitive and to have an attractive currency (in line also with requirement 3), the problem of a sudden increase in the size of ECB's balance sheet and consequently an increase in the risk of Central Bank should be avoided. However, the possibility could be taken into consideration that some specific group of non-euro citizens will have access to Digital Euro in some specific scenarios, as when visiting European countries.

Furthermore, there is also the risk of "currency substitution" which could lead to political tensions and increase a gap between rich and poor countries.

In addition, related to the possibility to have a remunerated currency, two additional issues should be faced. Firstly, the chance of attributing different levels of remuneration based on citizenship or location should be tested before the issuance of CBDCs (in case Digital Euro will have an international role). Secondly, rates applied to different CBDC will determine the market and the attractiveness of each digital currency. Thus, coordination of central banks would be crucial to secure a balance in the currency market.

5.5. Transfer Mechanism.

In several analysis about the CBDC infrastructure it is common to find a discussion regarding the usage of an account-based system or a token-based approach. To be fair, the report written by the ECB's task force (3) does not mention "token", rather a bearer instrument. In fact, they underline the concept that a bearer Digital Euro would not be forced to be based on a Distributed Ledger Technology, leaving "bearer" as a wider term to express several possibilities.

However, the main difference between an account-based system and a "token" based system is how authentication works. In the first system, a third part determines whether a transaction is correct and thanks to the link within banks updates both balances, payer and payee, accordingly. In this scenario, the relevant question for the recipient of the payment is "Are you really the account holder?". On the other hand, in a token approach, the payer and the payee are the direct responsible to verify the correct payment between them. The greatest difference is that with the last approach, the identity of the payer is irrelevant; here, the fundamental question is "Is this object I'm receiving real or counterfeit?". From a technical standpoint, the main difference is how ledgers are recorded. An account-based system records ledger as a list of accounts, each of which has a corresponding balance. Nowadays, it is the most used approach by major electronic payment solutions. By contrast, a token-based system has a ledger with a list of tokens with their corresponding values. When a payment is made, a token can be created or destroyed, but cannot be partially spent. One of the advantages of a token-based solution is the feasibility to mimic the features of cash. The degree of privacy could be really consistent, guaranteeing the impossibility to manage information of payer/payee by a third party. However, a bearer Digital Euro would mean a lower control by European Central Bank, implying the impossibility to limit holdings and restrict Euro usage outside of European Union. The situation would be even worse in the case of an offline payment, an unfeasible solution in an account-based system.

In the end, seems clear that an account solution is preferable by the ECB, but the absence of non-cash like features and a possible low attractiveness for end consumers, should be analyzed in detail.

5.6. Payment device

About this topic, there are just two possible choices to make. On one hand, a web-based service which uses internet connectivity and the set of already established devices as mobile phones or computers. On the other hand, smart cards. The latter would need compliance of specific devices, also with the possibility of an offline use. The distinction between online and offline payments and which of the two is preferable represents a further issue in the debate between privacy versus accountability. An offline payment is concerning for a series of reasons. First, a new set of devices should be trusted and with them also their developers. Furthermore, the absence of a third party able to check the transaction could enhance the risk of counterfeiting or hacking actions. This could be potentially disruptive for the overall economy, having a non-constrained monetary base and an unjustified inflation. A final notation is related with the other huge topic of a CBDC: the importance of managing the total amount in circulation of Digital Euro collides with an infrastructure which supports offline payments. This is probably the most synthetic way to face one of the most important issues of a generic CBDC. In the next paragraph this dichotomy will be the core of the discussion.

As concluded also by the report of the Task Force (3), a Digital Euro could be provided both by a web-based service and a physical device, highlighting already the possibility of a coexistence between offline and online payments.

5.7. Availability and usability offline

Offline payment is extremely attractive with respect to an electronic online payment because it guarantees the impossibility of sharing the transaction details with other parties beyond payer and payee. This scenario depicts a usage of CBDC like a classic cash transaction, gaining the trust of european citizens which would feel more comfortable using a currency as they are used to. Furthermore, availability of offline payments can be seen as an emergency measure, meaning a backup plan in situations where there is no possibility of going online.

From a technological standpoint, usability of an offline payment is already feasible. The existence of Smart Cards or some specific applications within mobile devices already allows offline payment systems to be used. A system of offline digital

wallets could be settled. In fact, a transaction could be performed as a transfer of pre-funded units between the hardware modules of payer and payee. Thus, a trusted device should only check the current balance and modify it in case there is a payment done. On the other hand, the payee is equipped with a terminal that just manages some main information to verify the validity of the transactions.
It is even possible that there will be a push towards a common European end-user solution in P2P scenario, one of the main scopes by ECB and more in general by the EU. In a wider vision, a Pan-European solution could be crucial to enhance the digitization of the european economy.
However, it is self-evident that an offline Digital Euro to be pre-funded in a "wallet" system was already existing in an online form. Hence, as the report made by the ECB remarks (3), any offline Digital Euro should also be linked to an online form of CBDC.

5.8. Remuneration

During this Thesis, it has already emerged the hypothesis to remunerate a Digital Euro. In the fourth scenario, it is analyzed a correlation between a remunerated Euro and monetary policy objectives. In the list of requirements to be satisfied, a level of remuneration for CBDC is a solution to avoid bank disintermediation and to prevent huge number of investments around the new currency. A scheme of remuneration could even be considered an attractive feature, gaining some competitive advantage with respect to other form of currencies.
The level of remuneration should be lower than commercial bank rates because the intrinsic risk is tinier, and a Central Bank is more reliable. However, it is important to underline once again that ECB should absolutely prevent a competition with commercial banks.
The type of remuneration required should be analyzed in detail and will be discussed deeply in the last chapter of the Thesis. Nevertheless, it is evident that a fixed interest rate should be equal to zero. A variable interest rate could adjust interest rate over time, maybe correlating the level of remuneration with monetary policy decision. A possibility hugely discussed in the contemporary economic literature is the link between a CBDC interest rate and MRO. Furthermore, a tiered

system is likely to succeed. In fact, less attractive interest rates to huge holdings of Digital Euro, as already mentioned, could discourage excessive use of CBDC as investment. The gap between levels of remuneration is another technical aspect which will be discussed further (in the final chapter).
Finally, it has to be noticed that the possibility of offline payments and the existence of pre-funded wallets represents an issue for a remunerated Digital Euro, being impossible to vary interest rate if a CBDC is stored offline.

5.9. Legal Tender

An economic definition of Legal Tender could be "anything recognized by law as a means to settle a public or private debt or encounter a financial obligation" (12). In each country, the national currency is a legal tender. Legal Tender is qualified as "desirable feature" by the ECB. However, it is more correct to say a "necessary condition" to be in a cash-like situation. Otherwise, Digital Euro would face the same problem of newcomers' electronic payment solutions.
A legal tender status implies that it will be usable in any place and under all conditions. In this scenario, Digital Euro would be more user-friendly, and it will drive towards a pan-european solution for end-users.

5.10. Parallel Infrastructure

It does not seem feasible to sustain a parallel infrastructure because costs would be relevant and supervised intermediaries would prefer to adopt an existing system to avoid risk and save marginality. The only reason to consider a new infrastructure is to prevent scenario five as cyber incidents or natural disaster, being always able to withstand these extreme events. There would be a sort of redundancy in payment solution, avoiding a total lack of transactions and enabling a continuity in the services thanks to a backup system. The balance of the two counterparts seems in favor of the first one, even if it depends on the likelihood of a "majeure force". Finally, a parallel infrastructure could represent a concern regarding environmental aspects.

5.11. Conclusion

After having listed all possible requirements that a Digital Euro should satisfy, it could be depicted a final synthesis to better frame potential problems. A new paradigm where CBDC enters in daily economy could face a clash between privacy and control. On one hand, citizens prefer some degree of privacy to preserve the cash-likeness of banknotes. In order to pursue preferences of europeans citizens, European Central Bank has two choices; either to introduce a type of CBDC which can be used offline and by means of specific devices or using a model of authentication made by tokens (rather than accounts) to preserve anonymity. These two approaches are similar but slightly different. A "tokenization" does not provide necessarily an offline system. However, an offline Digital Euro will enable payments with no internet connection and universal availability, being totally like banknotes. Eventually, an approach close to this scenario, could present a Legal Tender status in an easier way. On the other hand, European Central Bank need to manage the level of Digital Euro in circulation. Remuneration and restrictions are the two logical means to prevent huge amount of CDBC used as investment and currency substitution and huge flow of demand by non-european citizens. In case of an offline Digital Euro, there would be the impossibility to remunerate at a rate that varies over time (probably the rate would be zero as for cash). Furthermore, even if it is still a hypothesis, feasibility to adopt some monetary policies through interest rate on CBDC are on the table of discussion and do not allow an offline approach. In addition, supervised intermediaries could provide value-added services and strengthen the overall infrastructure.

However, it should be noted that this metaphorical confrontation between privacy of citizens and control by ECB could be unnecessary. In fact, as already stated, an offline Digital Euro would need to exist online at some point to fund payment device and to collect offline CBDC in a sort of withdrawal operation. Hence, a coexistence between the two approaches will be very likely to happen in the next future.

6. Difference Between CBDCs and Cryptocurrencies

It is a huge misevaluation to consider a Central Bank Digital Currency and a Cryptocurrency as equivalent. Even if there are some common points, which would be dependent on how CBDC would be implemented, there are clearly some differences which are at the core of the concept. To better understand these distinctions, it is necessary to have a clear idea of how cryptocurrencies work and the huge revolution which has been brought by them. Furthermore, it is important to split the discussion in two sections. First, an overview of cryptocurrencies from a technical standpoint and only subsequently an analysis crypto from an economical viewpoint. This division will also make clearer where there are huge distinctions between the two concepts and where it is possible to find similarities.

6.1. Data Structure

To understand what really a crypto currency is, is not an easy task. Nowadays, there is a strong debate around this topic. However, focus is more around investments and a sort of "gold-digger" dream, being totally forgotten the real meaning of a cryptocurrency and which are the innovations behind this concept. Since 2008 and the publication of the Protocol of Bitcoin (first crypto and the most important one) by Satoshi Nakamoto (pseudonym) (13), a general idea of circulation of money and bank system behind it has been questioned. In this Thesis we will try to list some general aspects of cryptocurrencies in order to reach a detailed description of them. The first big revolution in the introduction of a digital currency is which kind of data are recorded. For several years, banks have used an account system as a means to record data. The logic is simple: every customer has an account which records inflow and outflow transactions and make a balance to verify availability of cash. This sort of reasoning is how everyday people can pay digitally. The validity of the transaction is backed up by the bank of the payer and the payee with the help of payment service provider (Visa, Mastercard...). However, there are other possibilities. In the cryptocurrency's world, data record transactions rather than movement in a single account. Hence, data (technically Block) record a list of payments of different people. For instance, person A owes person B a certain amount of cash, person C gets money by person D etc. This is an example of what is called Ledger.

Theoretically, a Common Ledger approach is applicable in real life whether, for instance, people decide to lower the amount of daily transactions (with physical cash) and settle with real money each month. This is already a Ledger approach with a Protocol, or rather a set of rules common to everyone. The protocol in this simple case would be:

- Anyone can add lines to the Ledger
- Settle with real money each month (each period chosen by the protocol)

However, two problems arise from this system. First, how is it possible to trust every transaction written on the ledger? In fact, the sender (payee) has incentives to invent false transactions or modify the value of them to gain some fraudulent profits. Digital signature overcome this issue, guaranteeing a first layer of safety. A digital signature is a mathematical scheme based on a pair of keys (digital), one public and the other private or secret. Signature message is an output of a function which requires a specific message and the private key. Receivers verify the validity of the message through a Boolean function which asks as inputs the message itself, the signature, and the public key. Given the fact that the signature is dependent on the private key, the only way to identify the correct validation is guessing. The amount of tentative that a hacker should implement to find the correct signature is too hard computationally and thus makes the operation impossible.

A second problem with a General Ledger approach is that every payer should have a positive balance, otherwise the transaction is invalid. This requires a no overspending rule applicable to every user of the Protocol.

Hence, the Protocol should show these rules:

- Anyone can add lines to the Ledger
- Only signed transactions are valid
- No overspending

In this kind of approach, physical cash totally disappears. Theoretically, if the network is used by every citizen, cash would become useless. Furthermore, Bitcoin and most cryptocurrencies do not foresee a single centralized Ledger, rather a distributed one where there are identical copies for each peer of the network. Each ledger updates itself independently and then a consensus algorithm establishes

which copy is correct. Once consensus has been determined, all other ledgers update themselves in line with the correct copy. This is what is called Distributed Ledger Technology.

The revolutionary approach lies in the total absence of a centralized authority which verifies the validity of the transactions or, even more audacious, which manages the level of circulation of the digital currency. In this new world, Central Banks are not expected to exist. At this point, it could be clearer the focus of the ECB regarding Scenario 3 and the concerns around this topic.

To depict better how a cryptocurrency regulate itself and the amount of liquidity in circulation, it can be taken as an example Bitcoin, the most important and famous "crypto" around the globe. The currency conceived by Satoshi Nakamoto is based on a particular cryptographic function called SHA256. This function, used for many other applications (as the majority of crypto themselves), requires as input just any message and gives as output a two-hundred fifty-six string of bit (0,1) called "hash" or sometimes "digest". Eventually, SHA256 has two majors features which make this function incredibly famous. First, it is random. In fact, if you slightly change the message (input) the output will be totally different, being an unpredictable operation. Furthermore, inverse of this function is infeasible. It is not possible to guess the message having 256-bit string's, even if there is not a theoretical proof of the unfeasibility of this operation. The only possibility is guessing the right message, which is computationally unfeasible (one chance out of 2 elevated to 256, an astronomical number). Due to these reasons, SHA256 is used as Proof of Work in the Bitcoin world. Thus, a block (a list of transactions) is created only when someone is able to find a particular hash asked by the Protocol. In the case of Bitcoin, searched hash are the ones which start with at least with thirty zeros. Hence, a block is only considered valid when it has a Proof of Work, that is when its own hash starts with thirty zeros or more. The idea is brilliant. In fact, it is impossible to modify transactions contained in the block because otherwise hash changes (in a totally random way) being totally unlikely that the new hash starts again with thirty zeros. The Block becomes invalid. Nevertheless, the block structure was not considered safe enough and has been improved in a new scheme called Block-Chain. In this structure, a single Block contains inside its own message the Hash of the

previous block, precisely creating a chain. In this way, the Digest of a Block depends by the Hash of the previous one and so it continues until the source of the chain. This makes exponentially more resilient the system. In fact, if someone changes a transaction in a block, not only the hash of that specific block changes (making the Block invalid), but also the whole chain becomes invalid, being linked by their relative hashes. The only possibility would be guessing the right message for each Block rendered void by the structure, which is computationally unfeasible for a long chain. This is one of the safest ways to collect data and to guarantee their protection and security. Indeed, a Block-chain is called a Trustless system. A generic person does not need to trust anyone or any Central Authority, just the Protocol and the Algorithms which lies behind it.

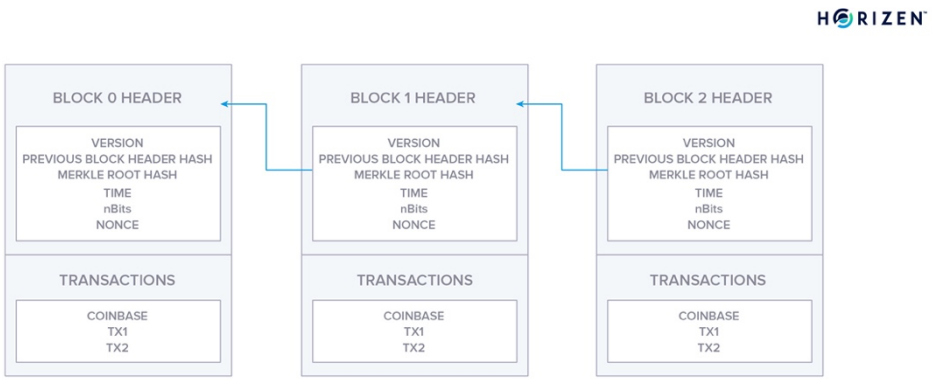


Figure 7: A simple representation made by the Horizen Academy regarding the Data Structure of a Blockchain.

However, the level of Bitcoin in circulation remains an issue. The real question is both to establish the number of Bitcoin in circulation and who performs this operation. However, also in this case, there is not the need of a centralized authority, rather of another rule of the Protocol, accessible to every peers. The rule is simple: every time a Block is created, a Block reward is given to the "miner" of the Block. Nowadays, the Block reward is 2.5 BTC per Block. This represents a huge incentive for people to try to find that valid Hash, which can create a Block, to secure transactions and to reward the miner. Note that a BTC has a value of around forty thousand Euro, thus implying a reward of one hundred twenty Euros for the miner. Bitcoin reward changes over time, following a harmonic function depending on the

number of Blocks created. Hence, in the first years of the newborn currency, rewards were larger (16 BTC) and in the future they will be tinier. It has been foreseen that in 2024 Bitcoin reward will become 1.25 BTC, guaranteeing the rate of creation of Block established in our days (1 Block every ten minutes).

To have a clear representation in mind of a data structure of a Block-chain, in the following pages an example of how sensible data are recorded within this new paradigm will be shown .

Figure 8: Example of a simplified valid Block with its own Hash done in Blockchain Demo.

This first image represents in a simplified way the meaning of a Block. It can be seen that there is the final Hash, representing the output of the function SHA256 for the input "Hi" combined with the nonce equal to 13631. Now, the concept should be clearer. If the message contained in data slightly changes, Hash will be totally different, having a high probability (close to one hundred per cent) that it will not start with four zeros.

Figure 9: example of an Invalid Block with its own Hash which does not respect the Protocol (start with n zeros)

As it has shown in the image, just adding a comma to the message, the Hash completely changes, and the Block becomes invalid. To render valid again the Block, a user should mine the data, meaning he should run the nonce until he will find a number able to have as an output a hash with four initial zeros (this is the trivial concept of mining). Notice that Bitcoin Protocol requires thirty zeros as initial values, making extremely computationally demanding the task. The Proof of Work's concept is based on these ideas.

The Block-chain concept represents just a sequence of Blocks, where each Block has also recorded the hash of its previous Block.

Figure 10: Example of a simplified Block-Chain

The idea is brilliant. In this way, the data structure is way more resilient to changes. Suppose a hacker would like to change Data inside the first Block. This operation changes the Hash of the first Block, eventually changing the whole chain, rendering void every block following the Block modified one. In order to make valid again the entire chain, a user should be capable to re-mine every invalid block to find a hash compliant to the Protocol, an unfeasible operation for long chains. Furthermore, there is not only a central copy, rather distributed copies, each for every peer of the network. Hence, it is impossible to modify chains already used by others, unless someone can constitute a new chain longer (more computing power, the

consensus algorithm of the Block-chain) than the other ones, an operation unfeasible unless you do not own 50% plus one of the Hash Rate of the entire globe.
It should now be clearer that this data structure, being so safe, can be used to record payment transactions, rather than insignificant messages.

Figure 11: Example of a simplified Block-chain used to record economic transactions

In the example shown in the figure above it is used a Fiat currency (Euro). However, it could be invented a new currency, being the system decentralized and trustless; a this is the reason of the new-born currencies.
Notice that all the concepts listed above are the basis to maintain stable the data structure, being almost impossible the possibility to change Blocks already created. However, the validity of the payments listed in a Block is guaranteed by the public-private keys and the system of digital signatures, which prevents the invention of false transactions in the network.
Finally, it can be seen an example of a real record of data transaction in the Block 316888 of the main chain of Bitcoin, which has recorded 323 transactions and has been created the 22nd of August 2014.

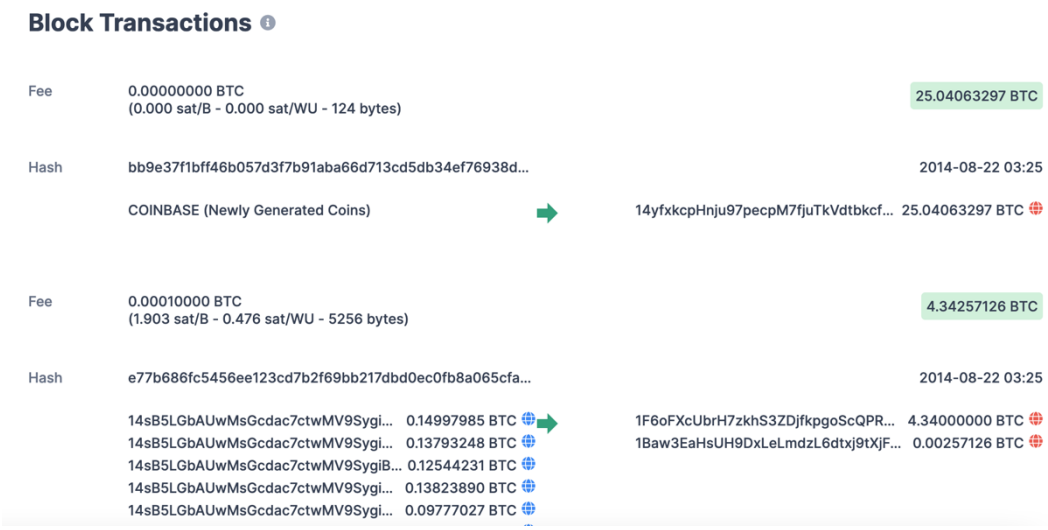


Figure 12: Real transactions recorded by the Block 316888 in the Block-Chain of Bitcoin. It can be seen, as first transaction, the block reward sent to the miner of the Block

6.2. Differences between CBDC and Cryptocurrencies

Despite what discussed previously, it is not clear which could be the differences within a CBDC and a cryptocurrency. In fact, substantial differences are not due to the Data Structure. A Central Bank Digital Currency could have different conceptual designs, raising the debate between a Token-based system versus an Account-Based system. Hence, it is not impossible to see some prototypes of CBDC leaning towards a Distributed Ledger application with a Block Chain structure that supports the system. In this scenario, differences are more conceptual rather than technical. In fact, there is a general misleading on how Cryptos are revolutionary for the economic world. Bitcoin and its similar have an ideological impact, not due to their cryptographic function or their type of data structure, but due to their decentralized system, a "trustless" system where no one is more relevant than the others (peer to peer), with the scope of democratizing the financial system. On the other hand, CBDC turns in favor of Central Bank and a centralized system, with the direct control of ECB (or its similar). This leads also to a topic already discussed during this Thesis: data privacy and anonymity. The European Central Bank and its own CBDC are likely adverse to emphasize privacy of data. First, they must obey to specific regulations as AML. Second, ECB is really worried about the possibility of an increase in the size of its own balance sheet, due to foreign investors, and regarding

bank runs and their disintermediation. In fact, the European Central Bank has a close control to the level of monetary base (M0) within the Eurozone, being one of the drivers for inflation. All of this requires a certain amount of control to establish some threshold or requirements to European and non-European holdings. Eventually, it seems unlikely a total anonymity in a CBDC world. Furthermore, a blockchain CBDC can experience larger surface for cyber attacks having more centralized points of failure which do not exist in a cryptocurrency scenario.

In addition, the system of Block rewarding to add more cryptocurrency in circulation totally disappears in favor of a centralized issuance by the European Central Bank. Hence, the number of Digital Euro in circulation would not depend on the number of transactions recorded in the "chain", but rather on the type of monetary policy established by the Central Bank (restrictive or expansive).

A deeper difference is that in a cryptocurrency there is not a framework designed to sustain its value and to guarantee protection to direct holders. Being a peer-to-peer network, only the Protocol set rules and does not exist a regulation to sustain the currency. This is the reason why crypto are highly volatile, do not have any intrinsic value (not backed by "something"), and they are traded like a speculative commodity. In turn, their market is illiquid and could show some failures in converting back the Euro initially invested. Notice that a huge volatility makes also practically impossible to use cryptocurrencies in daily transactions, being too high the cost opportunity to use that amount of currency knowing a possible rise in its own value. On this level, CBDC would totally equal to a FIAT currency, but digital. As every FIAT currency, it has not an intrinsic value, but it is backed by the Government that issued it and by the National (European) Bank who monitors the purchasing power.

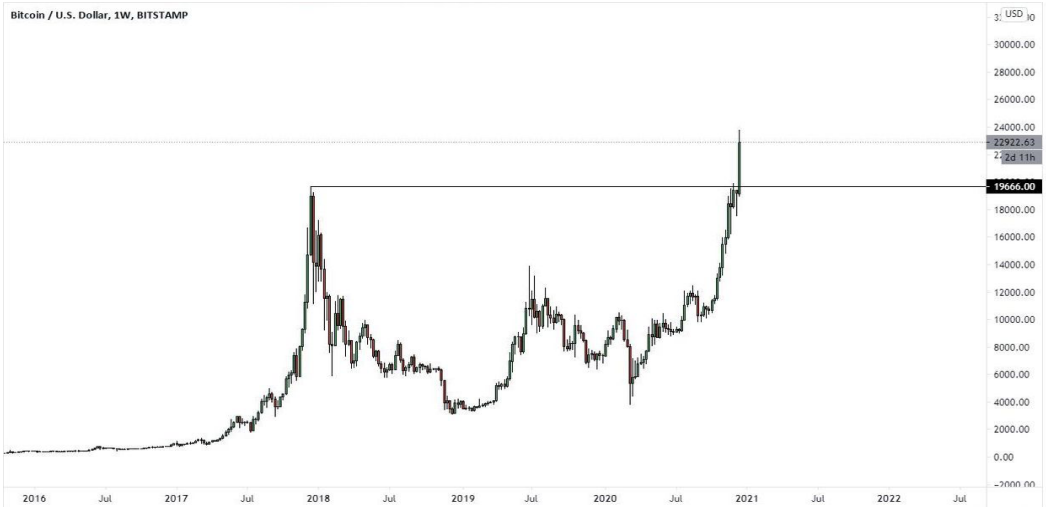


Figure 13: Volatility of Bitcoin in the last four years, showing a trend as a speculative commodity. In this graph the exchange rate is BTC/USD.

Notice that, from an economic standpoint, a digital euro would be a liability of the European Central Bank and therefore by definition risk-free Central Bank money. It would have exactly the same features of the actual cash for which ECB guarantees that value does not changes over time and the purchasing power remains stable. However, it would be different respect to commercial bank money which are by contrast liabilities of supervised private entities. Commercial bank money is created through fractional-reserve banking, a practice where banks are required to hold a proportion of their deposit liabilities and are free to lend the remaining amount to borrowers. This feature guarantees that the money supply on the market grows beyond the level of the base money initially issued by the Central Bank (the so called "multiplier effect"). It should be fair to say that reserves only cover withdrawals on the average pattern. In case of a shortfall situation interbank lending market comes to help or even Central Bank as lender of last resort.

Finally, the great dilemma is not about data structure or other technical features, but rather regards a vision of how economy should be run. There is a clash between data privacy and supervision of centralized authority, between the feasibility of an autonomous system and a monetary policy established by a Central Bank, between a self-regulated currency where everyone counts equal and a supervised currency who theoretically guarantees stability of purchasing power and a risk-free asset.

The ultimate debate is around the role of trust. Two options are available: trust a centralized authority who could either fail or support currency in period of crisis, or promote a trustless system where currency is not liable to anyone and thus there is no framework to sustain its own value.
The new-born stable coins affect this debate, being a sort of new player on the field, representing a middle ground solution between Crypto and CBDC.

Table 2: Final Comparison between a Crypto-currency and a Central Bank digital Currency.

	Cryptocurrency	CBDC
Economical role:	Liability to anyone	Liability of ECB
Purchasing Power:	Variable	Constant
Risk:	Speculative Commodity	Risk-free
Volatility:	High	Low
Backed by:	Any intrinsic value	Any intrinsic value. As every FIAT currency, based on trust towards Central Bank
Issuance:	Block Reward or similar	Monetary Policy, expansive or restrictive.
Privacy:	Anonymous	Holders' data
Restriction:	None	Regulated for non-euro citizens and a holding's threshold

7. Bank disintermediation and a two-tier remuneration system

The last section of this Thesis will be devoted to a deeper analysis of the problem of bank disintermediation and to how it can be solved with a two-tier remuneration system. As already highlighted in the first implication (chapter 4.1) related to the issuance of Central Bank Digital Currency, the introduction Digital Euro causes strong concerns for the stability of the bank system and the overall credit system. To have a clear idea on how CBDC could shape a new equilibrium around the economic system, it should be studied how balance sheet of major players would be changed.

7.1. Bank disintermediation

Initially, let's suppose that do exist two types of substitutions. First, a banknotes substitution, where citizens prefer to have an amount of digital money rather than some physical ones. It is not known how big this substitution would be. Let's call this amount of money $\boldsymbol{CBDC_1}$. Second, it exists a different type of substitution, where people withdraw ("substitute") money from deposits and shift to CBDC's holdings. Notice that, as already explained, Digital Euro would be a risk-free asset like banknotes and in periods of crisis it could be really attractive with respect to sight bank deposits with a low level of remuneration and always some sort of risk (bank default). These movements could be called $\boldsymbol{CBDC_2}$. Commercial banks will try to prevent a huge shift from their deposits, trying to be more attractive and maintaining a deposit base. However, this would imply higher funding cost for banks and would impact seigniorage income.

The Central Bank would try to avoid a huge funding gap from commercial banks in the economic system. Hence, the Central Bank would loan the exact amount of money moved by the disintermediation to commercial banks. However, this is not totally desirable from both sides. An increasing dependence of banks to the European Central Bank (or similar) could lead to an unfair competitive advantage and an inefficiency in credit provision, being not the core-competence of a Central

Bank. A possible tool to avoid this problematic scenario is the purchasing of government and corporate bonds made by the ECB, whereby owner of bonds could be either households or banks. In the Report issued by the ECB called "Tiered CBDC and the financial system" (14), authors differentiate $\boldsymbol{S_1}$, bonds owned by households, and $\boldsymbol{S_2}$, bonds owned by banks. Both cases are able to reduce the dependence of a commercial bank from a Central Bank. In fact, S_2 simply reduce asset-side in the balance sheet (having less owned bond) and at the same time reduce the dependence of the commercial bank from Central Bank, reducing credit from it. On the contrary S_1 do not impact asset-side. It has been assumed in the report that "the households will not keep the money obtained in the form of bank deposits but would purchase bank bonds that the banks would in addition issue" (14). The final result is clear:

$$\text{Central Bank Credit} = \text{Central Bank Credit} + \boldsymbol{CBDC_2} - \boldsymbol{S_1} - \boldsymbol{S_2}$$

As already noticed, purchasing governments and corporate bonds helps commercial banks to be less dependent from Central Bank Credit. However, an increasing dependence from a centralized bank seems unstoppable.

It is important to underline that this scenario will impact the funding cost of banks. In fact, usually central bank credit and bond issuance are more expensive than rate of deposits. However, the situation changes when the interest rates are negative. Central Bank credit is nowadays cheaper than deposit rate, being MRO rate settled to zero, while deposit rates have been settled slightly positive. For instance, between 2009 and 2018, considering the average interest rate, deposit rate has been more expensive than MRO, being 0.78% against 0.50%. Hence, it would not be a concerning problem in the short term. Nevertheless, interest rates would probably change in some future, reverting to their original structure (without negative interest rates). In that situation, funding sources of commercial banks would become more expensive, and the only possibility for a Central Bank would be lowering the monetary policy rate. However, this action would probably be not enough. Due to the existence of other type of financing in the economy (as market-based), Central Bank would lower monetary policy rates to achieve an average funding cost unchanged,

not totally offsetting the impact on bank funding cost, but only partially so. In the new equilibrium, bank will have lost competitiveness and will lose some market shares.

There is also another problem which concerns economists. It exists a possible issue regarding collateral scarcity. It is important to remind that every time central bank credit increases, a collateral counterpart should be given to the Central Bank as warranty for their loans. Notice that nowadays the quota of bank funding linked to the Central Bank credit is around five per cent of the overall funding. However, if this amount will increase consistently, banks should not only face an increase in funding cost, but even a huge demand for collateral. To be fair, the European Central Bank states that "only if $\boldsymbol{CBDC_2}$ takes much larger dimension, then an issue related to the centralization of credit would emerge" (14). In fact, substitution of bank deposits with Central Bank Digital Currency has a maximum around eight trillion Euros (it is the case where every sight deposit becomes CBDC), and only for value close to this level, the collateral scarcity issue could arise. In a more likely scenario, banks should be capable of providing collaterals, probably compelling European Central Bank to accept a new collateral framework, to approve some type of assets it previously did not accept (mortgage loans).

Nevertheless, the real question is whether it is acceptable that Central Banks become an important element of the credit allocation process. Central Bank itself likely prefers not to be a financial intermediary. One hypothesis is that this huge shift of $\boldsymbol{CBDC_2}$ in the liabilities side of Central Bank could be matched on the Central Bank asset side by higher holdings of government bonds, in order to avoid a huge dependence on Central Banks credit from commercial banks. In this way, Central Bank would also prevent to have a credit risk intense portfolio of securities. Notice that this solution is strongly dependent on how big the shift would be from deposits to Digital Euro (how great would be $\boldsymbol{CBDC_2}$).

Furthermore, there is another aspect to be discussed. Bank runs are a phenomenon which happens in a cyclical way. Central Bank Digital Currency could emphasize their negative effect during a financial crisis. Being risk-free, Digital Euro could be hugely more attractive to citizens with respect to deposits, completely crowding out

them. Considering this aspect, issuance of Digital Currency could hamper the credit provision and the banking system, in particular in a case of systemic banking crisis. Somebody argues that this is a view too catastrophic, since when there is a bank run, there is not only a "run" into banknotes, but also there is the possibility to move money into other deposits with other banks, or to place money into non-bank deposits with the Central Bank. Indeed, the contribution of a run from bank deposits to banknotes is the smallest compared to the other factors (14). Since CBDC should be like banknotes, they would not be the major factor of bank runs in a crisis period.. All in all, the question is not whether CBDC could hamper banking system in a financial crisis, rather in which measure it would be relevant.

7.2. Possible solutions

The possibility that CBDC pays an adjustable interest rate is often taken into consideration. Kumhoff and Noone (cited in (14)) justify this hypothesis addressing the problem of a price to equilibrate demand and supply. In their opinion, without an adjustable interest rate, in a theoretical oversupply situation, there would be a depreciation relative to other form of money or an inflationary situation bringing the value of CBDC in line with the real demand for them. Despite these emerging problems would be in fact challenging, the European Central Bank disagrees with this point of view, remarking that there are not distinctions with banknotes in this scenario. In other words, it could be asked why the issues raised by Kumhoff and Noone are not bound also to banknotes in circulation. In the current economy when there is an oversupply of banknotes, it automatically happens a sort of re-taking of money in excess into the Central Bank. There is no reason to think differently in a Central Bank Digital Currency scenario. Even inflation does not seem a concern, as an over-supply in banknotes is not considered a possible cause of inflation.
However, there are some advantages in having an interest rate on Digital Euro. First, it can change in parallel to monetary policy rate. In fact, many experts consider almost an absurdity the fact that a banknote has a fixed nominal interest rate despite the level of short-term risk-free rate. Nowadays approaching the zero lower bound level or even surpassing it, could be one of the reasons of a great attractiveness by

banknotes/Digital Euro. Furthermore, it is a tool to face a run into CBDC in case of financial crisis. It should be taken in consideration that a run into Digital Euro would be easier with respect to withdrawing huge amount of money or investing in other instruments, thus having an interest rate would be a disincentive in a systemic banking crisis.

In practice, a level of interest rate should be established as a spread with respect to some remuneration rate of monetary policy set by the European Central Bank. At present the Deposit Facility Rate has becomes as the only operational target of monetary policy. Hence, it is recommended that interest rate on Central Bank Digital Currency would be strictly linked with the level of DFR. In particular, the remuneration rate would be chosen "such that it would have a sufficient negative spread towards the short-term risk-free rate". Through this approach, it would be avoided that this new currency would store too much value and would lower the pressure on bank disintermediation and bank run during financial crisis.

Kumhoff and Noone (14) discuss other three possible principles. The first one is the possibility that reserves and CBDC are distinct and thus there is not a convertibility principle between them. The authors justified this proposal debating the separation of purposes of the two forms of Central Bank money. However, this is also true for banknotes and reserves without implying an impossibility to be convertible. The second principle state that banks could not guarantee convertibility of deposits into CBDC. In fact, banks should ask whether they would be able to meet the obligation in time of stress. Furthermore, the possibility to meet requests by citizens depends ultimately on the Central Bank itself. Banks, in a time of huge liquidity request, would turn in the direction of the Central Bank to sell or repo eligible assets. Hence, the credibility of the obligations depends ultimately by the Central Bank's commitment to be the lender of last resort. However, even in this case, it could be argued that this consideration could be applied to the banknotes too. Therefore, the real question is how to justify two totally different policies to be applied to Central Bank Digital Currency and banknotes. The last principle listed by the two authors regards the issuance of Digital Euro to be only possible against eligible securities.

The set of these four principles was hugely criticized by many experts, in particular because of afore mentioned problem of applying asymmetric rules to the digital and non-digital currency. Nevertheless, the first principle, i.e. addressing an interest rate to the CBDC seems reasonable and a huge dis-incentive towards a possible bank runs or a currency substitution.

It has been also discussed the possibility to cap the amount of CBDC per holder. This approach, already mentioned in this Thesis (Chapter 5.3), states that payments which would exceed an a priori threshold would be simply rejected. Eventually, a system which prevent overcoming a certain threshold seems feasible to be developed. It is kind of trivial for an account-based system, and ECB does not see great obstacles even in a Distributed Ledger Technology, the only problem being the efficiency of the system. It could be annoying for people to see frequently payment rejected by the system. A possible solution is a "waterfall" approach. Every user has a back-up account (in forms of Euro, not CBDC) where the amount in excess (or the whole transaction) is stored. This however means that every user of Central Bank Digital Currency must have this sort of "second layer" account, called waterfall account.

Principle of appliable interest rates on the CBDC's holdings and the possibility to cap the amount of owned digital currency leads to a solution already used for other instruments: a tier system. This will be the topic of the next section which will propose it as the final solution to address the problem of bank disintermediation.

7.3. Two-Tier remunerated system

Based on what discussed in the section before, an unattractive interest rate on CBDC seems to be able to avoid a bank disintermediation (cyclical or constant). Nowadays, the interest rate should be probably negative. However, there is a given threshold where a too much negative interest rate could be likely not considered acceptable by the public and by politics. Hence, question arise on what action has to be taken in case where interest rate is set at the lowest politically acceptable level and nevertheless a huge amount of money shifts from bank deposits to risk free digitally liabilities to the ECB.

To solve this problem, a tiered system is the ideal solution. A tiered system is based on the idea to remunerate with different level of attractiveness based on the amount of deposit held (usually with a negative correlation). Hence, in a two-tier system relatively attractive interest rates are applied up to some given "roof", and lower interest rates are applied for amount beyond that threshold. An approach of this sort has been already discussed by Panetta (11), while discussing the above-mentioned cap of holder's amount and the waterfall approach. Indeed, the two principles are the pillars to create a tier system. In addition to that, tiered systems are already used in the present economy. Reserve tiering systems have often been applied by the Central Banks for the remuneration of deposits. Nowadays, government deposits are ruled by a two-tier system where holdings exceeding two-hundred million euros or the 0.04% of the Gross Domestic Product are remunerated with an interest rate equal to zero. Furthermore, if economic situation is below the Zero Lower Bound, government deposits are remunerated with an interest rate lower or equal to the Deposit Facility rate. It has been previously observed how the DFR is the target for every other interest rate in the economy, and thus it is plausible that a tier remunerated system for CBDC would have as a benchmark the Deposit Facility Rate itself. There are several examples of tier-system. Even in Europe, since the launch of Euro in 1999, there was a tier system to differentiate required reserves and excess reserves, where the formers were remunerated at the level of MRO rate and the latter to a zero-interest rate.

The fact that this instrument has been already utilized is a demonstration that Central Banks know how to handle this kind of tool.

Pros seems to largely exceed cons. The most important advantage is that with a tier system, ECB can divide scope of money in levels and manage them with different policies. In fact, Tier 1 would be assigned to a payment function, whereas Tier 2 would have the scope of a store function. Negative or not attractive interest rates on the Tier 2 would probably prevent that CBDC would become a large-scale store of value. In addition to that, Digital Euro would remain attractive for the public, being the Tier 1 not disincentivizing and thus considering CBDC as valid means of payment. Overall, thanks to a tier system, Central Banks would have a better control on the amount of Central Bank Digital Currency, which is always a desired feature.

Finally, Central Banks could avoid political tension caused by suspects of potential money expropriation. In this respect, they should be strongly clear to communicate at an early stage that a two-tier CBDC is not meant to be attractive. However, regarding Tier 1, it could be promised to never charge negative rates.

Having depicted the reasons of why a tiered system interest rates is the most promising system to prevent huge negative effect in the economy and credit sector, we must determine the two main features of this approach. First, the level of the cap, thus the border where Tier 1 ends and Tier 2 starts. The European Central Bank estimates a quota of Tier 1 equal to 3.000 EUR per capita. In the Best Case, the one where every Euro citizen holds at minimum the quota of CBDC equal to the Tier 1, and assuming a population close to 340 million, CBDC in circulation would be around 1 trillion. It is not surprising that this figure is close to the level of banknotes in circulation, being banknotes and CBDC interpreted as money to cover the function of payment rather than store value or investment. Supposing a shift towards Central Bank Digital Currency of this entity, there would be no need of a large-scale credit operation. In fact, the balance sheet of Commercial Bank would be marginally impacted, and they will not face a relevant increase in the funding cost. More important is that Central Bank would not supply huge amount of credit towards banks, avoiding acting as financial intermediary, sticking to its own competences. In addition, Central Bank could even supply more CBDC in case of a decrease of the level of circulating banknotes, increasing Tier 1 accordingly (inverse relationship). In fact, it is important to remember that $\boldsymbol{CBDC_1}$ is not endangering economic stability, maintaining balance sheet constant (just a currency substitution, same balance on credit).

It is also interesting to analyze the level of Tier 1 to be applied to companies. This topic has not been discussed in the literature yet. However, it is obvious to say that Tier 1 should be much larger. It should be proportional to the size of the company and to the amount of payment transactions performed by it, maintaining the same scope to handle payments, rather than store value. On the other hand, it could be decided a Tier 1 equal to zero for both financial and non-financial corporates.

At the same time, level of rates should be implemented. Attractive level of rates for Tier 1 should be set, while dis-incentive rates would be linked to the Tier 2. Let us

call r_1 the interest rate applied to Tier 1, while r_2 will be called the interest rates applied above a certain threshold. The simplest approach proposed by the European Central Bank (14) is that r_1 would be a relatively attractive level, related to the remuneration of bank reserves (as un upper bound) or in a ZLB are not lower than zero. On the other hand, r_2 should be rather unattractive, less than deposit bank and short-term investment, even considering risk premium. However, it should be always related to the rate of bank reserves in order to enable the two rates to co-move in parallel, with some exception in the Zero Lower Bound zone. It is important to underline the fact that these two rates would not be considered as a monetary policy rate, rather they would just try to keep a similar spread with respect to monetary policy rate as MRO or Deposit Facility Rate.

Hence, the possible tier system considered by the ECB is:

$$\begin{cases} r_1 = Max\ (0; DFR - 1\%) \\ r_2 = Min\ \ (0; DFR - 1\%) \end{cases}$$

Where DFR is equal to the Deposit Facility Rate.

This system enables the rates of Tier 1 to be always greater than zero (at least equal to zero, in a case where DFR is lower than 1%), having at the same time an upper bound related to the Deposit Facility Rate. In this case the upper bound is 1 point percent below the DFR. Regarding r_2, there is a clear upper bound which is equal to zero. This rate would never be positive, at its maximum it could be neutral.

This system is just a possible approach of a two-tier system. The main character is the spread with respect to the DFR ($\Delta, equal\ 1\ \ in\ the\ system\ above$). Δ could change based on the policy established by the European Central Bank and depending on which are the main concerns of the Council. For instance, in case the European Central Bank will be worried regarding the attractivity of the Digital Euro it could lower Δ to a value of 0.5, decreasing the gap with respect to the deposit facility rate. On the other hand, in case the Central Bank would be concerned by a

excessive success of CBDC, it could apply a system of $\Delta = 2$, to be less attractive and lowering the possibility of a bank disintermediation.
However, it could be suggested that the Δ should be different for the two levels of rates. Indeed, scope of rates is different, having Tier 1 just a purpose for daily payments, while Tier 2 more a store value function.
It could be so expressed a generic system:

$$\begin{cases} r_1 = Max\ (0; I_{dfr} - A\%) \\ r_2 = Min\ (0; I_{dfr} - B\%) \end{cases}$$

- $r_1 \in [0; DFR]$; the greater is A, the less attractive would be the Digital Euro. It could be applied a low value of A to compete with crypto-currency and stable-coins.
- $r_2 \in (-\infty; 0]$; the greater is B, the less possible would be a bank disintermediation or a bank run in financial crisis. Lower bound could be theoretically minus infinite, however there are some politically acceptable minima.

To conclude, notice that in case A=B, and DFR=Δ (=A=B), $r_1 = r_2 = 0$.

Below some graphical examples are shown of how rates would have been changed in the past twenty years if there would have been a two-tier system as described before. In the first case there is an example where A=B=1, representing a moderate case implemented by ECB. In the second case, A=0 and B=2, it is supposed a scenario where European Central Bank decides to be strongly competitive in the payment sector, while avoiding bank disintermediation effects.

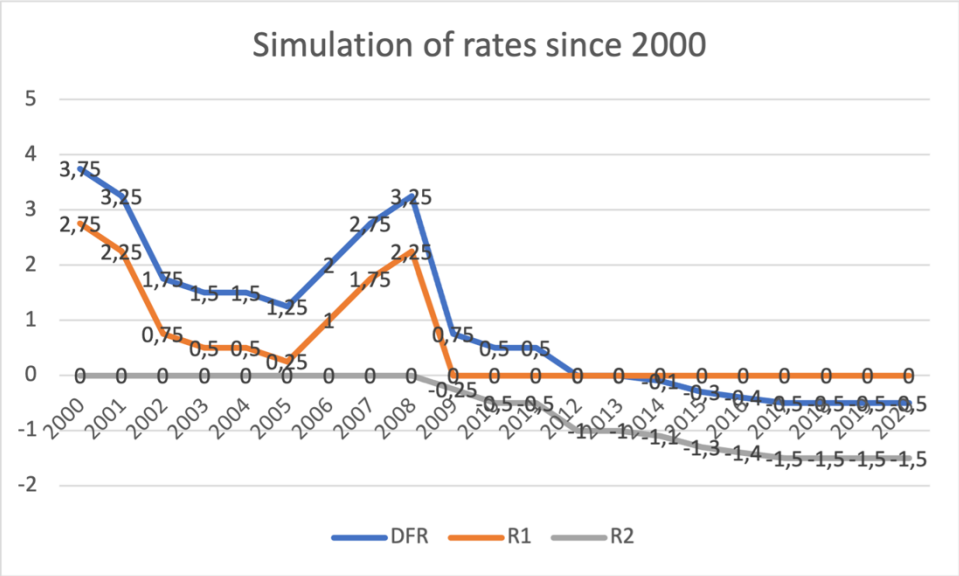


Figure 14: The figure shows how the rates implemented in a two-tier system would have been changed following DFR trend. In this case, A=1 and B=1.

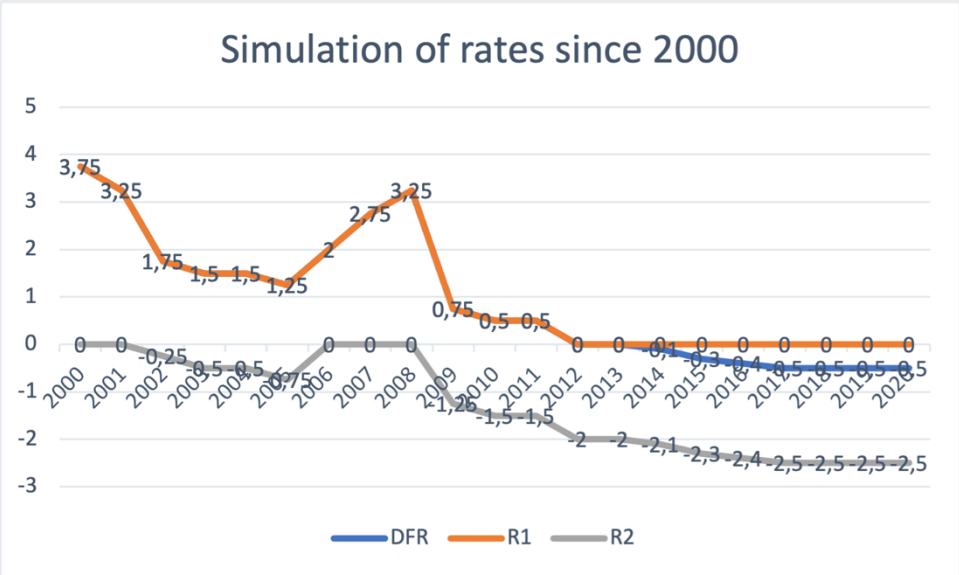


Figure 15: The figure shows hoe the rates in a two-tier system would have been changed following DFR trend. In this case, A=0, B=2.

8. Conclusion

In this Thesis it has been analyzed the whole set of possible scenarios, implications, specifications, and solutions regarding the issuance of a Central Bank Digital Currency. It has been examinate the situation in the Euro zone using as a reference several studies issued by the European Central Bank.

It is possible to conclude that ECB is worried by three specific problems. Firstly, how the role of money is changing. Young generations prefer to pay digitally rather than physically for several reasons. Eventually, the role of money will become more a store of value than a means of payments. In a safe period, when interest rates will increase, money could be owned even less, loosing attractiveness with respect to other form of storing value. Hence, ECB could raise the question whether it is possible or useful to sustain an infrastructure which could disappear in the medium-long-term. Secondly, crypto-currencies and other CBDCs are increasingly present in the market. Crypto currencies, which currently are volatile and traded as a commodity, could become dangerous in case they solve these issues. Stable coins do not seem to be so far away from this scenario. The risk to lose the monetary base and the grip on the monetary policy could endanger the role of Central Banks. On the other hand, pilot projects already exist in China and in Russia. The European Central Bank cannot afford to remain behind other Central Banks. These actions impact the power of foreign currency and therefore foreign exchange rates. A third implication is the impact on the environment of using a digital currency rather than a physical one. Life Cycle Assessment demonstrated clearly that the ATMs and distribution phase of money are the most polluting in the life cycle of cash. It is trivial to say that this phase would be avoided with the usage of digital money. However, it is relevant that the infrastructure will be run without mining operations, which imply by definition a huge electricity consumption.

At the same time, the issuance of Digital Euro could have some negative effects. The most discussed one is a possible disintermediation of commercial banks. People could prefer to own risk-free asset as a CBDC, liability of the ECB, rather than store value on a deposit, liability of commercial bank, having always an intrinsic (low) risk. Banks could try to pursue a more customer-oriented policy (imply costs),

while they should be supported by more credit of the ECB. This action increases the exposure of the Central Bank and increases risks for all markets. Economic consequences could be a lower of supply of credit in the market, due to increased costs for commercial banks. Another issue is the risk exposure of ECB related to foreign investments and an unexpected increase in the monetary base, which ECB could be not able to control. Related to the disintermediation of banks, application of an interest rate and some possible LTROs to sustain banks exposed by the issuance of CBDCs could affect the "profitability" of the ECB.

Specifications derived by the previous analysis gravitate around topics such as anonymity and privacy requirements, restrictions on the individual holdings, infrastructures, and the legal tender status. It seems feasible to implement a coexistence between an offline Digital Euro, cash-like, available everywhere (even in the absence of connectivity) to boost privacy and anonymity, and an online Digital Euro, useful to control the level of CBDCs in circulation, to establish variable interest rates, and to limit the access or establish a maximum amount to individual holdings. From the concept of capping amounts of individual holdings and the one of remunerating Digital Euro derive the one of the two-tier system, hugely discussed in the last chapter. Its scope is clear: avoid disappearance of sight deposit, avoid a huge shift on the liability side of the commercial bank's balance sheet toward ECB credit, prevent that European Central Bank becomes a financial intermediary, escape from a possible increase of funding costs for banks with an impact on the overall economy. It is likely that in the next future a cap amount equal to 3.000 Euro per capita with rates related to the level of Deposit Facility Rate will be applied. The spread with respect to the DFR and differences between interest rates applied to Tier 1 and Tier 2 would be an instrument for the European Central Bank to promote Digital Euro as a means of payment and at the same time to prevent CBDCs as a store of value.

Finally, it has been analyzed how a crypto currency works and how a Block-chain data structure is implemented. Eventually, a CBDCs could apply the same mechanisms with no technological differences, but rather conceptual one. The real debate is not regarding a distributed system versus a central account system. The real point

is whether a decentralized system could be trusted, which implies the question on whether commercial and Central Banks are needed.

9. Bibliography

1.**European Union,** ***Treaty of the Functionin of European Union***, 1958.

2.**European Central Bank,** ***Monetary policy decision.*** **[Online] (https://www.ecb.europa.eu/mopo/decisions/html/index.en.html).**

3.Fabio Panetta, Yves Mersch, ***Report on a Digital Euro.*** **European Central Bank, 2020.**

4. A. Barret, ***Clash uses plunges during pandemic.*** **Financial Times. 2020.**

5. Fabio Panetta, ***Cash still King in times of COVID-19.*** **2021.**

6. Board, European Systemic Risk. ***Systemic Cyber Risk.*** **2020.**

7. Bank of America. ***Future of cross-currency payments.*** **2018.**

8. R. Hanegraaf, A. Larcin. ***Life cycle assessment of cash payments in the Netherlands.*** **2020.**

9. Investopedia. ***What is the environmental impact of cryptocurrency? .*** **2019.**

10. Brugge, ***Attacking cost of Cash.*** **MCkinsey&company, 2018.**

11. Fabio Panetta, Ulrich Nielsen. ***Central bank digital currency remuneration in a world with low or negative nominal interest rates.*** **2020.**

12.Investopedia. ***Legal Tender.*** **[Online] (https://www.investopedia.com/terms/l/legal-tender.asp.)**

13. Nakamoto, ***Bitcoin: A Peer-to-Peer Electronic Cash System.*** **2008.**

14. European Central Bank. ***Tiered CBDC and the financial system.*** **2020.**

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