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# Central Bank Digital Currency (CBDC)

*An Explorative Study on its Impact and Implications for Monetary Policy and the Banking Sector*

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# ABSTRACT

This thesis focuses on the concept of Central Bank Digital Currencies (CBDC) and the possible implications this could entail for monetary policy, commercial banks, and payment systems. With the declining use of cash and increased market capitalization of cryptocurrencies, central banks face an important decision. They need to consider the possible risks this change poses, and potential actions they could take to mitigate a potential weakening of their monetary authority. A CBDC could be a viable option to moderate this risk, but the potential impacts it can have are unknown. This study aims to understand the possible implementation of a CBDC and the effects this could have on monetary policy, commercial banks, and payment systems. Then, the ideal implementation for Norway is considered based on the knowledge gained throughout the thesis.

Through a systematic literature review, this thesis attempts to synthesize the information obtained into an overview of the current state of CBDC research. Therefore, an optimal strategy proved to be a thorough literature search in order to increase the likelihood that all relevant resources were considered. The selection of sources also went through a systematic process to ensure the validity and reliability of the selected literature.

The literature highlights two types of CBDC, retail and wholesale. This definition is divided further into token-based and account-based CBDCs. Research on monetary policy suggests a CBDC would be useful at mitigating the zero lower bound (ZLB), but the actual effect of moving the ZLB is unclear. Through a CBDC, an alternative to quantitative easing (QE) is possible, called helicopter money. It enables the direct injection of funds into the public, stimulating the economy. Commercial banks would likely need to increase the interest rate offered on deposit accounts if the CBDC is interest-bearing. Funding this increase can be done in various ways. Although a CBDC increases the ease of transferring funds into a risk-free asset, the findings do not indicate a risk of bank runs, as long as necessary measures are in place. Finally, the payment system can benefit from a CBDC, especially one based on blockchain technology, from lower settlement times and costs, with the added benefit of the security it offers.

# ACKNOWLEDGEMENTS

This master thesis is written as a part of our master's degree specialization in Finance at the Norwegian School of Economics (NHH). Motivated by the course FIE 448, Banking and Financial Technology (FinTech), held by our supervisor Professor Xunhua Su, we choose blockchain as our subject of interest. With the rapid development in blockchain and the introduction of Libra, we decided to pursue the topic of CBDCs. We found it a highly complex and demanding subject, but also an exciting and rewarding experience in terms of learning and developing our research capabilities.

We want to express our profound gratitude to our supervisor Xunhua Su for his invaluable feedback from choosing a subject to finishing the thesis. Furthermore, we wish to thank the authors of every report we have used, as their knowledge on the topic has been paramount for our thesis.

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# ABBREVIATIONS

ATM - Automated teller machine

CBDC - Central bank digital currency

DCA - Digital cash account

DLT - Distributed ledger technology

ELB - Effective lower bound

PSD2 - Revised Payment Service Directive

QE - Quantitative easing

RTGS - Real time gross settlement

ZLB - Zero lower bound

# 1. INTRODUCTION

## 1.1 BACKGROUND AND MOTIVATION

In 2008, the pseudonym Satoshi Nakamoto published a paper called "Bitcoin: A Peer-to-Peer Electronic Cash System." As the financial crisis was raging, the paper proposed a new decentralized system aiming at replacing third parties involved in transactions. The lack of confidence in the current system motivated this response. Through cryptography and a new consensus algorithm, Nakamoto programmed the Bitcoin protocols and created the genesis block on January 3, 2009. Trusting in a completely decentralized and open peer-to-peer network might have taken time, but as the general public started to acknowledge the technology, popularity surged, and the Bitcoin price peaked at $19 000 in late 2017 (Morris, 2017). Through the rise of Bitcoin, other developers have recognized the potential in this new technology and decided to launch their version of this new technology called blockchain.

Blockchain is hailed by many as a new technological revolution, able to decentralize every centralized function. The technology is still in an immature and conceptual phase, but innovation in this space has garnered the attention of the large corporations in the financial world. Facebook has launched its cryptocurrency initiative Libra, which will serve as a new currency to use in the Facebook ecosystem. Other private companies such as IBM and Maersk has also seen the possibility of utilizing this new technology in their operations. This development from a novel technology to a central part of the research in most large companies has also caught the attention of the central banks.

Central banks aim to regulate and stimulate the economy to maintain stability and increase employment. As the usage of Bitcoin and other cryptocurrencies increases, a more significant part of transactions within the central banks' jurisdiction consists of alternatives to fiat currency controlled by the central bank. This change might hinder their ability to use monetary policy effectively and could pose a genuine threat to their ability to regulate the economy. Such a concern increases as private companies are looking to build their cryptocurrencies. The central bank is often seen as a slow-moving, reactive institution, taking calculated low-risk decisions, but this rapid advancement in cryptocurrencies has prompted an investigation into the possibility of introducing a Central Bank Digital Currency (CBDC).

The motivations behind a CBDC are not solely these new cryptocurrencies. Several advanced economies have experienced a decline in cash usage, and a CBDC might be a viable alternative for keeping fiat currency relevant in a cashless society. As several of these economies have experienced stagnation in growth, and the central banks' interest rates approach zero or even negative values, the effectiveness of the policy interest rate is decreasing due to the notion of the Zero Lower Bound (ZLB). Quantitative Easing (QE) can stimulate the economy when the interest rate is at the ZLB, but there is skepticism surrounding this policy. A CBDC has the potential to lower the ZLB and increase the effectiveness of the policy interest rate as an alternative to QE. A CBDC could also open the possibility of new monetary tools, which the current system does not support.

One aspect of blockchain attracting considerable interest from the private sector is the possibility of increased transaction speeds and lower transaction time, while simultaneously providing an easily accessible distributed ledger. These aspects are also attractive to a central bank and might be a reason to explore the option of a CBDC based on this technology. Introducing a CBDC might initially look like a no-brainer; however, a crucial aspect of the current financial system is the involvement of intermediaries in virtually every transaction. The financial crisis in 2008 demonstrated the potential problems associated with an unstable financial system. Therefore, the introduction of a new currency in direct competition with some of the services that the commercial banks currently offer might be risky. Research on CBDC is in its infancy, and various areas need rigorous analysis and testing. However, the potential benefits have already prompted some central banks to launch pilot tests to figure out its implications. Emerging economies have often lagged in terms of technological innovation, but the potential advantages of a CBDC have incentivized some of these central banks to pursue CBDC tests.

The question of whether or not the central bank should issue a CBDC is a crucial consideration in the years to come. The literature on the subject is mostly scattered, and as the area is under rapid development, reports and papers are continually produced to identify and examine the implications associated with CBDC. As a result of this, the status quo is continuously changing, and understanding this subject is no easy task. Through a literature review, this thesis aims at synthesizing different views into a summary of the current state of CBDC research and applying this in a discussion on a case for Norway.

## 1.2 RESEARCH QUESTION

The purpose of this paper is to study the implication of implementing a CBDC using blockchain on a country's monetary policy, its commercial banks, and its payment systems. The thesis presents possible taxonomies of CBDCs and its implications, culminating in its ideal implementation in Norway. This paper attempts to report an in-depth and reliable summary of this technology. The thesis question is:

**How could a Central Bank Digital Currency be implemented, and what implications could this have on monetary policy, commercial banks, and the payment system?**

## 1.3 OUTLINE

Chapter 1 contains a presentation of the background, research question, and outline of the thesis. Chapter 2 includes the essential theory of blockchain technology, money supply, central banks, and commercial banking. To be able to examine the potential impacts of a CBDC, it is necessary to understand how blockchain differs from existing technology. On top of this, one must understand the tools at the central bank's disposal and how the policy interest rate affects commercial banks and the money supply within a country.

Chapter 3 includes the methodological approach used in this thesis, the reason a literature review fits the research question, and the strengths and weaknesses of this method. The chapter also describes the search terms used to find relevant literature and the evaluation of the chosen resources.

Chapter 4 introduces the concept of CBDC, how it relates to money and its functions, and its possible taxonomy. It gives a presentation of different types of monies that exist within the economy and highlights its three functions. Then retail and wholesale versions of a CBDC are reviewed, as well as their possible implementation.

Chapter 5 examines the possible motivations for implementing a CBDC and its challenges. The chapter highlights why central banks are currently investigating this innovation and what the side-effects could be. It also considers reasons for why a CBDC poses a challenge to central banks and regulators.

Chapter 6 reviews the effects that a CBDC could have on a country's monetary policy. It introduces research on the ZLB and examines the possibility of CBDC lowering this limit. A discussion on new and old monetary tools such as helicopter money and inflation-level targeting follows. There is also a consideration of potential effects on seigniorage. Finally, there is an examination of the possible threat to monetary control posed by private cryptocurrencies.

Chapter 7 considers the outcomes this technological advancement could have on the commercial banking sector. It includes an examination of bank funding with both an interest-bearing and non-interest-bearing CBDC. The discussion presents the changes that this possibly entails for commercial bank's interest rates, the change in bank lending, and the potential actions commercial banks might take. The section then considers how the digital nature of this new currency could increase the risk of bank runs. Finally, mentioning the possible private innovations in the light of this new system and its positive effects on commercial banks.

Chapter 8 views the implications of a CBDC on the payment system. It reviews the effects of introducing this class of money, specifically with blockchain, and its implication on conducting payments. The section includes an investigation of the security features that blockchain provides. It also considers the possible developments a CBDC could have on the FinTech sector. Finally, reviewing the effects of this digital currency on emerging economies.

Chapter 9 looks at the ideal implementation of a CBDC in Norway by considering the current situation in the country and combining it with all previous analyses and information. Chapter 10 gives concluding thoughts on the topic and areas of further research.

# 2. THEORY

## 2.1 BLOCKCHAIN

Blockchain is a decentralized distributed ledger. The ledger consists of blocks containing the record of transactions. Stored within the blocks is information on the transactions, including specific data, such as the header from the previous block. Blockchains are a long string of these blocks connected one after another, very similar to a chain.

Previously, the problem with digital cash was to determine if a token had already been spent, called the double-spending problem. With fiat currency, the money is tangible, so checking if the person possesses it is easy, but with a digital currency, this is harder. Until 2008 this had been done through a central authority like a bank, but when Satoshi Nakamoto introduced the idea of the blockchain, it effectively solved the double-spending problem without the need for a central authority.

### *2.1.1 Blockchain components*

The ledger in a blockchain network contains every transaction done since the inception of the blockchain. Through the use of a consensus protocol and robust cryptography, there is no need for a central authority, and every node in the network has its copy of the updated ledger at all times. This aspect removes the need for an intermediary to record all transactions, and participants can do transactions with each other "directly," effectively removing the traditional middlemen. Centralized systems have the problem of a single point of failure, and therefore redundancies are introduced. On the other hand, a decentralized system can function even if a large part of the nodes are failing, effectively eliminating most of this redundancy. The technology behind this invention is intricate, but by breaking it down into components, the concepts are easier to understand.

*Cryptography*

"Cryptography is the science of protecting information by transforming it into a secure format" (Christensson, 2015). While the concept of cryptography has been around for thousands of years, from simple substitution ciphers like the Caesar cipher to more advanced versions discovered by Arab mathematicians, the modern computer has changed the field entirely (Sidhpurwala, 2013). The immense computing power at our fingertips has fueled the development of more advanced cryptographic techniques, which today is one of the underlying principles of blockchain. It makes it both transparent and secure.

### *Cryptographic hash*

"Hashing is a method of applying a cryptographic hash function to data which calculates a relatively unique output for an input of nearly any size".(Yaga, Mell, Roby, & Scarfone, 2018, pg.7) If two entities where to hash the same data they would derive the same result, however, if some third party had corrupted one of the entities data the hash would be completely different and the entities would conclude that the data was tampered with. So a small change in the input data yields a completely different hash. The phrase "Central Bank Digital Currency" using the SHA-256 algorithm hashes to:
"978e4c2bed936b8acfac77a710f983e9207f6c023a865b5923ac3d67ac9454b4"
"Central Bank Digital currency" on the other hand hashes to:
"f440420cb6023085a0cd62eee7635e9a3b121477f3fdaa0b4fce800ce7f3fef8"
While the difference is just the capitalization of the last word, the output is completely different.
Cryptographic hashing has three important security properties (Yaga et.al., 2018):

1. Preimage resistant. It is a one-way hash, which makes it close to impossible (computationally infeasible) to compute the input value from the output value.
2. Second preimage resistant. One cannot find an input that hashes to a specific output. The only way is through a complete search of every combination, which computationally, is infeasible.
3. Collision resistant. There are never two inputs that hash to the same output.

In the blockchain network this hashing is used for:

1. Address derivation
2. Creating unique identifiers
3. Securing the block data - The blocks data is hashed and stored in the block header.
4. Securing the block header - The current block headers hash digest is stored in the next blocks header, securing and linking the blocks to each other. One can check that the hash digest is, in fact, the same in the header as in the block.

### *Cryptographic nonce*

A nonce is a random number used once, added to the end of the block information, before hashing it. In the Bitcoin network, the miner then checks if this hash starts with 17 "0" s. If it does, then the miner has found a hash that satisfies the current rule and appends the block. If the hash does not fulfill these requirements, then a new nonce is tried. This measure lets the same data that everyone possesses differ when hashed, and finding the correct hash is computationally expensive (Nonce, 2019).

### *Asymmetric-key cryptography*

Blockchain technology uses asymmetric-key cryptography that is a pair of keys: a public and a private key that are related to each other. The public key is used to make the address that all participants in the network can see, while the private key is only available to the owner. Although anyone can see the address, this does not reduce the security associated with the blockchain. An attacker cannot derive the private key from the public key (A Deep, 2019). The owner can use one to encrypt and the other to decrypt. This process enables trust between users by allowing users to verify the integrity and authenticity of the transaction while allowing the same transactions to remain public. A private key is used to encrypt a transaction so that anyone with the public key can decrypt it. By signing with the public key, the owner proves it has access to the private key. Private keys are used to digitally sign transactions while public keys are used to verify the signature (A Deep, 2019).

### *Address*

Transactions are made more straightforward by blockchain networks using addresses that work as a public identifier for a user. This process involves hashing the user's public key along with some other data determined by the blockchain. This implementation could be done through QR-codes, as they can be easily made to work with mobile devices. This feature simplifies the transaction process as connecting with others is quickly done through a mobile interface. It is also central for smart contracts as addresses are used to determine where to transfer funds (A Deep, 2019).

*Blocks*

A block in a blockchain contains a block header and block data. The header contains metadata for the block, including the hash of the previous block header and a hash of the block data. The data contains a list of validated and authentic transactions. Validating and authenticating the block is done by ensuring the transaction is formatted correctly and that each party has signed the transaction. These blocks connect by storing the hash digest of the previous block's header. This chain of hashed headers makes changing a previous block impossible, as this would alter the following headers (Frankenfield, 2019). Through consensus-mechanisms such as proof-of-work, going back through each block and altering the headers is both computational and time-consuming, to the point of being practically impossible.

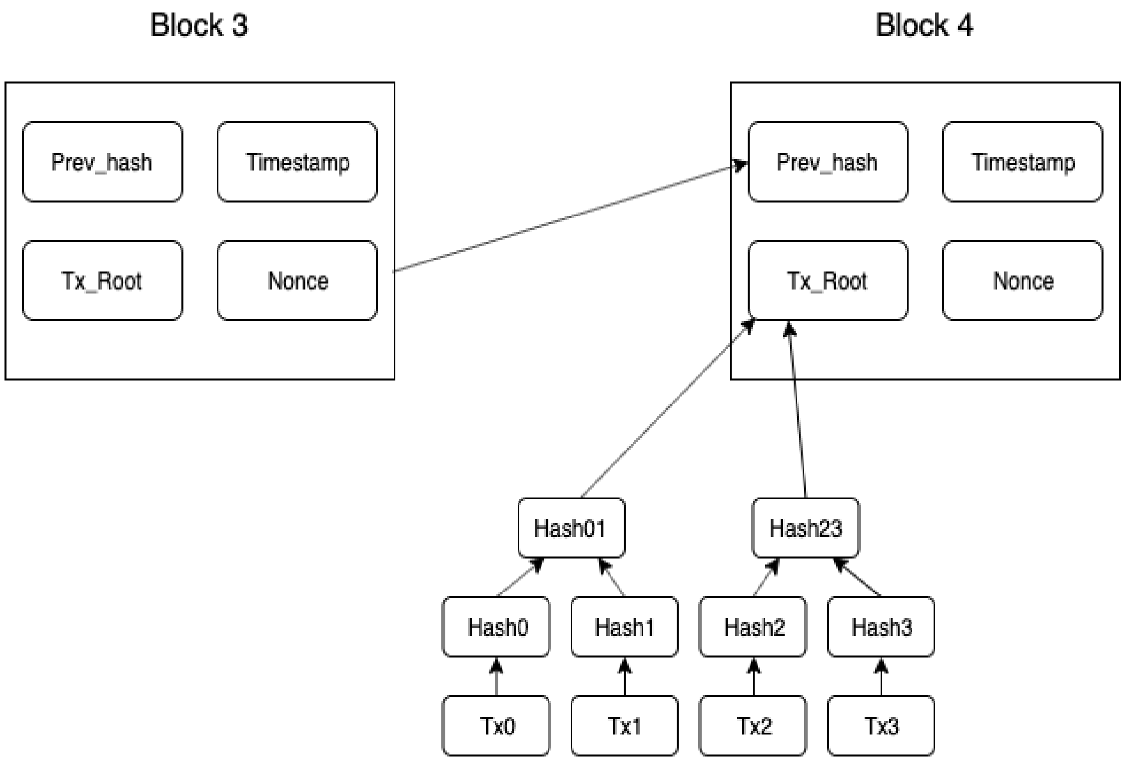


*Figure 1: The process of connecting blocks*

*Based on Rosic, 2019*

### 2.1.2 Consensus algorithms

The consensus algorithms are the mechanism for reaching consensus in a network. In a centralized system, there is a central authority that decides which transactions are valid and checks that participants follow the rules. A blockchain, on the other hand, is decentralized, but through a consensus algorithm, it enforces the protocol rules, making transactions in a trustless way, solving the double-spending problem. To understand the different consensus algorithms, the Byzantine General Problem illustrates the obstacles associated with a decentralized network and why a consensus algorithm is needed.

*Byzantine general problem*

With a central authority, the consensus mechanism is the board of directors and the managers. A decentralized peer-to-peer network solves this another way. The Byzantine Generals problem can illustrate this mechanism. Imagine a siege where there are multiple attacking armies led by several different generals scattered around the city, and their objective is to decide whether or not to attack. If they all attack at the same time, they will be victorious, attacking at different times ends in defeat. Without a central authority, coordinating the attack is very difficult. The generals communicate through letters, but due to messengers having to travel over a distance, they risk the capture of the messenger. There is no way to trust the letter once it arrives, as the opposing army could have intercepted the messenger and tampered with the message. The generals cannot trust the network (Rosic, 2018). This problem is related to peer-to-peer networks. How does one determine the validity of the data once it arrives without the use of a central authority?

Suppose the generals append a nonce, a random hexadecimal value, to the text in the letter. They then hash the text with the nonce appended. The generals have in advanced agreed only to share a message where the hashed text starts with four zeroes. If not, then they change the nonce and try again. This process is time-consuming and computationally expensive. If anyone tampers with the message, the hash will change, and the general who receives the message knows not to trust it (Rosic, 2018). However, the enemy can still capture the message, change it, and hash it, repeating until they find these four zeroes. Instead, the generals determine that the message will have to go through three generals each time, adding the message and hashing again, creating a chain of messages. This process is very time consuming, but if the generals send multiple messengers, the ones receiving these messages will only have to append them with the correct nonce, hash them and see if it matches. On the flip side, the enemy will have to crack the hash, change the message, hash it and send it between each general, a process that takes too long and would likely lead to the defeat of the city. This mechanism is the basis of how a decentralized network can achieve consensus with blockchain (Rosic, 2018). The algorithm ensures trust in a trustless system by tamper-proofing the system.

### *Proof-of-work*

The consensus model used by Bitcoin is called proof-of-work and is the most commonly used algorithm. To determine who will publish the next block, everyone competes to solve a computationally intensive puzzle. If one solves the puzzle, one proves one's work. Even though it is hard to find the solution, verifying it is quick, so all other nodes can authenticate it when it is published. The difficulty changes after a certain number of blocks, so the rate of new blocks is constant. The Bitcoin network aims for a new block every ten minutes. A drawback to this consensus model is the amount of energy used trying to solve the puzzle and receive the rewards for doing so. This limitation has led to many blockchains exploring new consensus models to become both faster and more eco-friendly. Such a system is also suspect to a “51% attack”, where if an attacker gains control of 51 percent of the network's computational power and it can stop transactions or even reverse past transactions.

### *Proof-of-stake*

The proof-of-stake consensus model bases itself on the idea that users with higher stakes invested in the system are more likely to want the system to succeed. The stake is the amount of cryptocurrency the user has. Once a user stakes his funds, these funds are unavailable. The greater the stake, the higher the likelihood for that user to be able to publish the block. Since this requires far fewer resources, one generally earns more on transaction costs instead of earning currency from mining. One problem with this consensus model is called the nothing-at-stake problem. In a proof-of-work model, there exists something called the longest chain rule. This situation occurs with the creation of two blocks simultaneously. The two blocks will separate and make different chains. The longest chain is accepted, and the contributors of the other chain do not receive a reward. This mechanism makes supporting the wrong chain costly. In a proof-of-stake model, due to no loss of computational power by supporting a chain, everyone would support as many chains as possible to increase the odds of winning. Ethereum is one of the biggest blockchains currently transitioning to this consensus model. Their solution is to use a system called Casper, which penalizes those who try to do a nothing-at-stake (Rosic, 2018).

*Delegated proof-of-stake*

A model building upon the proof-of-stake concept is the delegated proof-of-stake or DPOS model. The choice of block producers bases itself on a continuous approval voting system. Anyone can participate, and if chosen, they will be able to produce blocks. EOS apply this model for their blockchain. The production of blocks is in rounds of 21, automatically choosing the top 20 producers, ultimately choosing the last block producer proportional to the number of votes they receive relative to the other producers (Rosic, 2018). Block producers shuffle around randomly, and anyone that does not participate is no longer in consideration. They avoid the issue of forking as the producers cooperate instead of competing to find blocks. EOS has employed this model that, in theory, could scale to millions of transactions per second. The average time it takes to produce a block in EOS is currently 3 seconds.

DPOS builds upon the concept of modern democracy where the masses vote for delegates to express their interests (BitcoinWiki, 2019). In a DPOS, users stake their currency on a delegate that receives, verifies, and adds the new blocks to the blockchain. If a delegate is found to be malicious, the voters can remove their votes and the delegate from consideration. A problem with the DPOS model is that the delegates might create other users and vote on themselves, and with enough currency to stake, they remain in consideration, even though they are malicious. A solution to this is centralizing delegates, where they are pre-approved, and their identities are known, but this makes the system less decentralized and anonymous.

*Proof-of-authority*

The proof-of-authority consensus model relies on block producers to use their real-world identities to confirm who they are, thus if they act maliciously, their reputation will be lowered, and they will be less likely to be considered as a block producer. It is in the interest of the user to maintain a high reputation to be able to produce more blocks (Curran, 2019). The problem with a POA model is the need to confirm the block producers' identity through the blockchain and avoid impersonating. One of the main selling points for current blockchains is the pseudo-anonymity offered, which would be harder to guarantee in a POA model.

### *2.1.3 Access*

The configuration of a blockchain can happen in multiple different ways. Some are entirely decentralized, while others are semi-decentralized or even centralized. The structure is determined by the access the blockchain offers. Three properties describe this; read, write, and commit (Hileman & Rauchs, 2017).

- Read: Who can read the ledger and see the transactions.
- Write: Who can produce and write transactions to the blockchain.
- Commit: Who can participate as nodes in the network, and update the ledger.

The read property determines if the blockchain is open or closed.

- Public: Anyone can access and read the transactions on the ledger.
- Private: Restriction of access to the authorized nodes.

The write and commit properties determine who can verify the transactions:

- Permissionless: In a permissionless blockchain, anyone can generate transactions and update the distributed ledger.
- Permissioned: In a permissioned blockchain, only the authorized nodes can generate transactions and update the ledger.

Bitcoin is an example of a permissionless public blockchain, and these properties make it decentralized. On the opposite side is Libra, which is a permissioned private blockchain, not open to anyone but the authorized parties. These aspects make it more centralized.

### *2.1.4 Forks*

In a centralized system, updates are often done by gradually updating the software on a server. Because the entity updating has full control of the network, it is a relatively simple task. In a decentralized network, coordinating this process becomes much harder. Updates can change how the network behaves, consequently altering the consensus mechanism. Such revisions can be carried out in two ways. If the update is backward compatible with nodes not yet updated, it is called a soft fork. On the other hand, if the changes are not backward compatible, the old nodes will reject the blocks. This modification is called a hard fork and can lead to a split in the network, effectively creating multiple versions of the same cryptocurrency and the underlying blockchain (Blockgeeks, 2019).

### *2.1.5 Smart contracts*

Blockchain technology has enabled a new digital contract called "smart contracts." While standard contracts contain legal text written on a piece of paper, smart contracts consist of computer code and data, which is executable on the blockchain. This technology enables automatic contracts that are tamper-proof if programmed correctly. Ethereum has built its entire blockchain around the use of this new contract type. In standard contracts, each party has to check that what they are sending/receiving is per their agreement. This process involves considerable labor and is rather inefficient. Smart contracts automatically execute when conditions are met and transfers the correct funds. Therefore, one no longer needs to check funds received or paid manually. While a lot of smart contracts are somewhat rudimentary, more sophisticated uses are created as the technology matures.

### *2.1.6 Limitations*

The two most popular blockchains, Bitcoin and Ethereum, currently have low transaction speed, primarily due to using the proof-of-work approach. Bitcoin has a transaction per second speed of 7, while Ethereum has 15. In comparison, Visa is at about 1700 (Li, 2019). This limitation makes current blockchains less effective at conducting transactions compared to existing technology. Ethereum is switching to a proof-of-stake consensus model and adding other technologies to increase transaction speed. Other blockchains like EOS and XRP have already solved this limitation and have higher transaction speeds than Visa. If these new consensus models prove to be secure, it could bypass this limitation.

Previously, the use of cryptocurrencies for illegal activities has resulted in a negative connotation associated with blockchain. This perception makes the implementation of blockchain harder as there is less trust in this technology. The blockchains associated with these transactions could alter the properties of the underlying blockchain, but it would most likely change the basic principle of decentralization and anonymity.

## 2.2 MONEY SUPPLY

The money supply is the total amount of currency and other liquid instruments that, at a certain point in time, are in circulation within a country’s economy. This supply includes all physical money, such as notes and coins, checking and savings account, and all near money substitutes. The money supply can be broken down into four measures: M0 (or MB), M1, M2, and M3 (Chappelow, 2019).

M0, also known as MB or the monetary base, is the narrowest definition of money and only includes hard currency in circulation. This term constitutes the total amount of physical cash, in the shape of banknotes and coins, distributed within a country's economy. Only the central bank can create money that falls within this definition. It also includes all financial institutions deposits of cash in the central bank, though this is technically not in circulation (Chappelow, 2019; Norges Bank, 2017).

M1, referred to as narrow money, is a standard measure of money supply and includes M0, in addition to checking accounts and other checkable deposits. This supply includes all deposits in transaction accounts in either commercial banks or the central bank. They are technically out of circulation, but the owner of such an account can withdraw these deposits on demand from the bank, be it a commercial or central bank (Chappelow, 2019; Norges Bank, 2017).

M2 includes M1 as well as savings accounts and certificates of deposit. This definition constitutes all money, domestic and foreign, in deposits redeemable at notices of up to three months or with maturities of up to two years. These accounts are slightly less liquid than M1, but can nonetheless be retrieved relatively quickly (Chappelow, 2019; Norges Bank, 2017).

M3, which is usually called broad money, is the sum of M2 and includes more sizeable deposits, institutional money market funds, and other more substantial liquid assets. The assets included in this definition are not as liquid and can be referred to as "near, near money," as it includes the finances of larger institutions and corporations, as opposed to individuals or small companies (Chen, 2019).

## 2.3 CENTRAL BANKS

The central bank is responsible for stabilizing the national currency in a country or union, prevent high inflation, and maintain financial stability. It achieves this through the use of monetary policy and regulation of commercial banks and financial services. As the world has evolved, the central banks have as well. Through various financial crises, the tools of the central bank have improved, and are now an integral part of any nation.

### *2.3.1 Monetary policy*

Every country wants to have high employment and rapid growth while maintaining price stability. The main instrument for achieving this is monetary policy. The aim is to manage the size and growth rate of the money supply in an economy. There are multiple tools at the central bank's disposal for altering this supply and maintaining stability in the economy.

*Interest rates*

Central banks offer a base rate on short-term loans for commercial banks. When commercial banks offer customer loans, it is at a premium above this base rate and is the way they earn profits. If the base rate increases, the cost of borrowing rises for commercial banks, which in turn will result in a higher interest rate for the general public. Therefore, the cost of borrowing increases, which leads to less of an incentive to take out a loan. This measure effectively decreases the money supply. The inverse happens when decreasing the base rate, which lowers borrowing costs and money flows into the economy, increasing the money supply (Corporate Finance Institute, 2018).

When the economy is in distress, the money supply usually shrinks due to the uncertainty associated with the future, as more people hold on to their funds as opposed to investing. To combat this, the central bank usually lower rates and try to stimulate investments. Commercial banks have a deposit account in the central bank where they store excess cash. In some extreme cases of low growth and low inflation, central banks have enforced negative interest rates on these deposits in an attempt to incentivize bank lending. However, there is a limit to how low the interest rates can go called the effective lower bound, ELB, or zero lower bound, ZLB. For Japan and some of the western countries in Europe, this limits their ability to use interest rates to stimulate the economy (Kihara & Koranyi, 2019). The reason there is an ZLB is that if the interest rate is negative, banks would instead hold cash, resulting in the central bank looking towards other tools to stimulate the economy.

*Reserve requirements*

Every commercial bank is required to hold a percentage of their lending amount as a reserve. This reserve acts as a buffer and a source of liquidity. If the central bank decides to increase the amount each bank is required to have, the commercial banks have less money to lend, and the money supply decreases. In the US, this ratio is at 10 percent, while in the eurozone, it is one percent (Bennett & Peristani, 2019; European Central Bank, 2016).

*Open market operations*

The central bank can purchase or sell securities issued by the government in an attempt to change the money supply (Corporate Finance Institute, 2018). By buying government bonds from banks, they pour money into the banks and the economy, increasing the supply of money. Conversely, a sale of government bonds to banks decreases the money supply and increases the interest rates.

*Expansionary vs. contractionary*

When the central bank increases the money supply in an economy, it is called an expansionary policy that aims at stimulating the economy and fuel growth. However, the downside to this is higher inflation. This policy is carried out through decreasing interest rates, lowering reserve requirements, or purchasing government securities. The opposite is contractionary policy aimed at decreasing the money supply and in turn, inflation. This strategy achieves this by raising interest rates, increasing reserve requirements, or selling government bonds. The central bank aims to use these policies to keep financial stability.

### *2.3.2 Regulating financial institutions*

"Financial regulation refers to the rules and laws firms operating in the financial industry must follow" (Central Bank of Ireland, n.d.). The main reason the central bank regulates banks is to ensure financial stability. Reserve requirements are a form of regulation, but other functions include ensuring adequate risk controls and only allowing firms who have shown that they can fulfill specific criteria to operate in this sector. These requirements ensure financial stability but also guarantees that consumer protection is in place. Central banks make sure that firms follow these rules through constant supervision of the financial institutions. There is closer supervision put on larger commercial banks due to the potential risk they pose (Central Bank of Ireland, n.d.). In the event of a bank violating the rules, the central bank has the power to restructure a financial institution completely.

### *2.3.3 Financial crisis*

The central bank also has a unique role in case of a financial crisis. Multiple tools can be useful in stopping a bank run and avoiding a financial crash. A bank run occurs when the liquidity of banks becomes constrained and the public attempts to withdraw their deposits, leading to solvency issues.

*Suspension of convertibility*

When banks mostly consisted of physical locations, people who feared a default on their deposits would stand in lines to withdraw their funds from the banks. A common tactic used by the authorities was closing the banks for some time, which prevented people from withdrawing their funds. As banks have evolved and are now mostly digital, this is very rarely the case and only occurs when banks are entirely out of money. Other options, such as borrowing money, has decreased the use of this method.

*Coalition of private banks*

Banks can band together and form a coalition so that a claim on one bank converts into a claim on this coalition. This measure reduces risk and lowers the likelihood of a full-blown bank run. Another benefit from this is banks monitoring each other, reducing the chances that they are operating irresponsibly. Such a coalition does not work in the case of all banks suffering from a shock and is, therefore, most effective against smaller shocks, not system-wide bank runs.

*Government deposit insurance*

The central bank can guarantee the deposits of customers through government deposit insurance. This course of action acts as a promise in the event of a bankruptcy, where the central bank promises that it will pay the deposits that would otherwise be lost. While this policy has ended bank runs almost entirely, there is still the risk of the government behind the guarantee running out of money. An example of this is Greece. A solution proposed to combat this is that the entire eurozone backs the banks. If a bank in Greece were to go bankrupt and Greece's central bank was unable to cover the deposits, other members in the eurozone would compensate for this.

*Capital requirements*

Capital requirements are a specific ratio that the banks must have concerning their debt to equity. Through this requirement, the central bank can decrease the number of banks that are over-leveraged, which in turn reduces the chance of bankruptcy. Regulating commercial banks is central to reducing risks.

*Lender of last resort*

The central bank can act as a lender in situations where a bank is unable to provide credit from other sources. This measure is a kind of emergency lending which aims at providing funds to calm the public when it believes a bank is running out of liquidity. A problem associated with this is that it might make banks less cautious if they believe they can always receive an emergency loan. Such excessive risk-taking could potentially lead to higher chances of crisis, but it has been effective against bank runs as a supplement to government deposit insurance.

*Government bailouts*

In recent times some governments have bought large parts of a bank's toxic assets to remove them and stabilize the bank. This strategy is highly controversial, as the public often perceives this as a reward for a bank's recklessness through the government bailing them out when in trouble. This action is known as the too-big-to-fail policy. Government bailouts were a central part of the financial crisis in 2008, where the US purchased billions of toxic assets in an attempt to stabilize the economy.

## 2.4 COMMERCIAL BANKING

"A commercial bank is a type of financial institution that accepts deposits, offers checking account services, makes various loans, and offers basic financial products like certificates of deposit and saving accounts to individuals and small businesses" (Kagan, 2019). Most people use commercial banks for their daily banking needs.

### *2.4.1 The assets of a bank*

According to James Tobin (1982), we can divide the assets of a bank into two categories, loans and investments or defensive assets.

*Loans and investments*

The loans and investments held by a bank are illiquid and unpredictable in value in the short term, usually held till maturity (Tobin, 1982). The commercial bank provides loans based on the deposits that they hold. Sometimes they will have less money than what is needed to cover their loans and will, therefore, borrow from the central bank. One of the primary roles of the commercial banking system is to issue loans to customers on which the banks earn interest. This income stream is one of their primary sources of revenue. The interest rate offered to customers is usually determined by the base rate set by the central bank. Commercial bank's profit on the spread between the rate they offer their customers and the base rate (Duff, 2019).

*Defensive assets*

The term defensive assets refer to currency, deposits in the central bank and other banks, overnight loans, well-secured call loans, treasury bills, and other papers of equivalent quality.

Generally, a bank will hold more than the required reserves, but short term or overnight borrowing from other banks or even the central bank can offset this. The difference refers to the bank's defensive position. There is a requirement for liquid assets in the case of unusual deposit withdrawals or extraordinary demand for loans (Tobin, 1982).

### *2.4.2 Interest rates*

"The rate of interest measures the percentage reward a lender receives for deferring the consumption of resources until a future date. Correspondingly it measures the price a borrower pays to have resources now" (Malkiel, n.d.). One of the main functions of a commercial bank is lending to customers and receiving interest on these loans. To determine the interest rate, the central bank sets a base rate that the commercial banks follow. The possibility of default associated with lending, compels the bank to charge a premium on top of the base rate to compensate for this additional risk. When the central bank raises/lowers the base rate, the commercial banks respond by increasing/decreasing the rates they offer.

There is another interest rate commercial banks must also consider. The banks store the excess cash in a deposit account with the central bank. Usually, the banks earn a specified interest rate on this excess cash; however, due to low economic growth, some countries have implemented negative rates on these deposit account. The idea is to force the banks to lend out all excess cash in an attempt to stimulate the economy. However, there is a lower bound to this rate. If the interest rate is higher than the cost of holding physical cash, banks will switch to holding cash if this were to occur.

# 3. METHODOLOGY

This chapter examines the methodology used to answer the thesis question outlined in the introduction. There is a presentation of the research method, the search terms used, and an evaluation of the sources.

## 3.1 RESEARCH METHOD

Research methods are the strategies used in the collection of data or evidence for analysis to create a better understanding of a topic (Research Methods, 2019). Due to the complexity and lack of consensus on this topic, as well as the relative uncertainty surrounding the research question, a qualitative research method is a natural fit. There are no central banks that have implemented a fully-fledged CBDC, with most still in the research phase. Only a handful of central banks have started experimenting with digital currency, though these are mostly in the initial phases and have not been applied using blockchain. The consequence of this is the limited amount of numerical data available, which made it impossible to conduct a quantitative method (Saunders & Thornhill, 2016). Another argument for the use of qualitative research is due to the comparative absence of previous analysis, either quantitative or qualitative, on the actual effects that a CBDC could have. Because of this, there is a futurist perspective associated with this topic, which is a type of research that a qualitative method tends to be more efficient at resolving.

Qualitative research methods serve the purpose of being able to take a deep-dive into the desired topic while granting the researcher flexibility in terms of the structure of the investigation (Saunders & Thornhill, 2016). This approach permits potential changes of emphasis during the research process, and as it progresses, one can efficiently and effectively go back and forth between gathering data and the research question (Saunders & Thornhill, 2016). Therefore, it can adapt to the quality of the information gathered. This ability is essential when researching a topic were the amount of available data is scattered, rather nonuniform, and possibly factually lacking. The differing views on CBDC's and its potential effects meant that it is critical to evaluate the data gathered continuously and how it relates to the overall research. Another strength associated with qualitative research is that complex data can be incorporated together to generate conclusions with more depth and accuracy (Regoli, 2019). Current CBDC investigations are being conducted by a multitude of different players, with differing preconceptions and goals associated with their research. Due to this, the complexity linked with the collected data increases, as views on this topic can differ substantially. Therefore, having the ability to combine all this information and evaluate its validity and factuality through reviewing the literature, facilitates in producing stronger conclusions (Ridley, 2013).

In-depth interviews were a possible research technique, but due to the lack of experts with thorough knowledge of monetary policy, CBDC, and blockchain, the number of possible interview subjects was limited. Though there is no set rule on the number of subjects that are needed to research a given topic, it is said that saturation is achieved when 12 individual interviews of a homogenous group have been conducted. At this point, the data achieves the rigor and trustworthiness needed (Guest, 2006). As a result, this led to the rejection of this method. The effectiveness of the analysis would have suffered from a lack of reputable sources.

Several central banks and individual researchers have conducted investigations into the potentials and the problems associated with CBDC, though the body of research on this topic is somewhat disjointed. The focus on blockchain as the primary mechanism for this implementation is also lacking. Therefore, a literature review, more precisely a systematic search and review, was chosen as the method for this paper. Such a review is a widely used qualitative research method when addressing broad questions in an attempt to produce the best synthesis of evidence or data (Ridley, 2013; Cantrell, 2019). A strength of this technique is its ability to identify and bring together research from a broad spectrum of sources. It accomplishes this with minimal repetition and being able to discover gaps or oversights that exist in a body of research (Cantrell, 2019). Therefore, this is the ideal method for the topic of CBDC, as research on this subject is in its infancy and consequently has no centralized and easily identifiable consensus. A systematic literature review can achieve this.

As with every research method, there are downsides associated with conducting qualitative research and specifically a literature review. A drawback of conducting a literature review is due to the limitations associated with obtaining all relevant papers on a topic. There is no set method for covering all relevant documents on a topic, which can lead to an increase in the amount of bias associated with the review (Ridley, 2013; Cantrell, 2019). Therefore, conducting a thorough literature search in order to increase the likelihood that all relevant resources were considered proved to be the optimal strategy. On top of this, papers cited within this literature were added and considered for relevance to the research question. Section 3.1.1 shows the specific parameters for the literature search.

Another weakness is because there is significant subjectivity associated with qualitative data. This limitation means that researchers could highlight different aspects of an investigation and put more importance on specific issues that might be considered irrelevant to others (Regoli, 2019). It could be highly problematic when conducting a literature review as it makes the analysis of several different viewpoints time consuming and makes it considerably harder to find a consensus amongst the sources in terms of the research question (Ridley, 2013). When considering the shortcomings of this paper, this was one of the main issues. By evaluating the resources used, it remedied this to a certain extent, in an attempt to make sure that they could be considered trustworthy sources. Section 3.1.2 shows this process.

Finally, a literature review is based solely on secondary sources in an attempt to summarize already established research on a topic. This limitation is in and of itself, not a problem. However, without the inclusion of any primary data, attaining any new ideas or concepts are difficult (Ridley, 2013; Regoli, 2019). This aspect of a literature review can be problematic for a master's thesis. Chapter 9 solves this issue, presenting a case for the ideal implementation of a CBDC in Norway. It takes all the previous knowledge highlighted by the secondary sources, as well as specific information about blockchain that was not considered, in an attempt to discuss the ideal way of implementing a CBDC in Norway.

### *3.1.1 Literature search*

Table 1

*Concepts and keywords used in literature search*

| Concept | Keywords |
|---|---|
| Blockchain | "Distributed Ledger*" OR "Bitcoin" OR "Ethereum" OR "Proof-of-work" OR "Consensus algorithm" OR "Cryptography" OR "EOS" or "Speed" |
| Central Bank Cryptocurrency | "Central Bank Money" OR "Fiat Money" OR "Fiat Currency" OR "Blockchain" OR "Distributed Ledger" OR "CBDC" OR "Money Supply" OR "Central Bank" OR "Payment Systems" |
| Central Bank Digital Currency (CBDC) | "Fiat Currency" OR "Digital*" OR "Government e-money" OR "CBDC" OR "Digital e-money" OR "Distributed Ledger" OR "Fiat" OR "Money" OR "Technology" OR "Research" |
| Commercial Banks | "Funding" OR "Lending" OR "Assets" OR "Balance sheet" OR "CBDC" |
| Monetary Policy | "Interest Rate" OR "Central Bank" OR "Quantitative Easing" OR "Money Supply" OR "Currency" OR "Impact" OR "Base rate" OR "Deposit insurance" OR "Lender of last resort" OR "Bank runs" OR "Seigniorage" OR "Zero lower bound" or "Open market operations" or "CBDC" |

*Note:* The literature search was conducted in Oria and Google Scholar.

Based on Pongiglione, De Stavola & Ploubidis, 2015.

### *3.1.2 Evaluation of Sources*

Determining the credibility of the sources used in this literature review was essential. Therefore, there were specific criteria that the resources utilized in this analysis had to fulfill. The absolute gold-standard for emphasizing the reliableness of an article or paper is that it has been peer-reviewed. However, due to CBDC's being a relatively new topic and the full understanding of its implications and importance is unknown, it complicates the process. Hence, other standards were set to determine the credibility of the literature used.

The first pertains to the timeliness, signifying that a paper needs to be recent enough in time to be relevant to the topic. This criterion meant that a paper needed to be written within the last ten years to be included, due to the technology (blockchain) being a relatively new concept (Cantrell, 2019). However, exceptions in terms of obtaining a more comprehensive understanding of underlying theoretical concepts were made, such as the "zero lower bound."

The second criterion relates to whether the authors/publishers of the paper are an authority on the topic at hand (Cantrell, 2019). This measure is, to a certain extent, hard to establish, given how recent CBDC has emerged as a viable option for central banks. However, if the central banks or organizations such as the International Monetary Fund (IMF) or the Bank for International Settlements (BIS) commissioned the authors, authority is most likely established.

The final criterion concerns the number of times others have cited a specific piece of literature. The total number of references an article has in other research can provide an indicator of its trustworthiness, though it is not an absolute measure. The fact that others have trusted a specific source can give it a certain level of credibility, though others can have also cited a source as an example of false or incorrect information. Therefore, this criterion is not an absolute indication of a source's validity.

Table 2

*Evaluation of sources*

| **Researchers** | **Institution** | **Title** | **Cited**[1] | **Year Published** |
|---|---|---|---|---|
| Adrian | International Monetary Fund | Paving the Way for Fintech | N/A | 2019 |
| Adrian & Mancini-Griffoli | International Monetary Fund | The Rise of Digital Money | 16 | 2019 |
| Andolfatto | Federal Reserve Bank of St. Louis | Assessing the impact of central bank digital currency on private banks | 21 | 2018 |
| Arteta et al. | Koç University-tüsiad Economic Research Forum | Negative interest rate policies: Sources and implications | 69 | 2016 |

| | | | | |
|---|---|---|---|---|
| Auerbach & Obstfeld | National Bureau of Economic Research | The case for open-market purchases in a liquidity trap | 276 | 2003 |
| Barontini & Holden | Bank for International Settlements | Proceeding with caution - a survey on central bank digital currency | 14 | 2019 |
| Barrdear & Kumhof | Bank of England | The macroeconomics of central bank issued digital currencies | 181 | 2017 |
| Bech & Garratt | Bank for International Settlements | Central Bank Cryptocurrencies | 192 | 2017 |
| Benos et al | Bank of England | The economics of distributed ledger technology for securities settlement | 33 | 2017 |
| Berentsen & Schar | Federal Reserve Bank of St. Louis | The Case for Central Bank Electronic Money and the Non-case for Central Bank Cryptocurrencies | 49 | 2018 |
| Bordo & Levin | National Bureau of Economic Research | Central Bank Digital Currency and the Future of Monetary Policy | 119 | 2017 |
| Buiter | London School of Economics and Political Science | Negative nominal interest rates: Three ways to overcome the zero lower bound | 226 | 2009 |
| Chapman & Wilkins | Bank of Canada | Crypto “money”: perspective of a couple of Canadian central bankers | 3 | 2018 |
| Chiu et al. | Bank of Canada | Central bank digital currency and banking | N/A | 2019 |
| Committee on Payments and Market Infrastructures (CPMI) | Bank for International Settlements | Central Bank Digital Currencies | N/A | 2018 |
| Danezis & Meiklejohn | University College London | Centrally Banked Cryptocurrencies | 187 | 2015 |

| | | | | |
|---|---|---|---|---|
| Dyson & Hodgson | Positive Money | Digital Cash<br><br>Why central banks should start issuing electronic money | 45 | 2016 |
| Eichengreen | National Bureau of Economic Research | From Commodity to Fiat and now to Crypto: What does history tell us? | 11 | 2019 |
| Engert & Fung | Bank of Canada | Central bank digital currency: Motivations and implications | 53 | 2017 |
| Fung & Halaburda | Bank of Canada | Central bank digital currencies: a framework for assessing why and how | 74 | 2016 |
| Goodfriend | The Ohio State University Press | Overcoming the zero bound interest rate policy | 412 | 2000 |
| Hamilton & Wu | National Bureau of Economic Research | The effectiveness of alternative monetary policy tools in a ZLB environment | 637 | 2011 |
| IBM & OMFIF | Official Monetary and Financial Institutions Forum | Retail CBDCs - The Next Payment Frontier | N/A | 2019 |
| IBM & OMFIF | Official Monetary and Financial Institutions Forum | Central Bank Digital Currencies | N/A | 2018 |
| Jobst & Lin | International Monetary Fund | Negative interest rate policy: Implications for monetary transmission and bank profitability in the euro area | 113 | 2016 |
| Kahn, Rivadeneyra, & Wong | Bank of Canada | Should the central bank issue e-money? | 13 | 2018 |
| Kumhof & Noone | Bank of England | Central bank digital currencies - design principles and balance sheet implications | 46 | 2018 |
| Keister & Sanches | Federal Reserve Bank of Philadelphia | Should central banks issue digital currency | 8 | 2018 |
| McAndrews | Asian Development | The Case for Cash | 20 | 2017 |

| | | | | |
|---|---|---|---|---|
| | Bank Institute | | | |
| Meaning et al. | Bank of England | Broadening narrow money: monetary policy with a central bank digital currency | 33 | 2018 |
| Norges Bank | Norwegian Central Bank | Retail payment services | N/A | 2018 |
| Norges Bank | Norwegian Central Bank | Central bank digital currencies | N/A | 2018 |
| Norges Bank | Norwegian Central Bank | Central bank digital currencies | N/A | 2019 |
| Pfister | Banque De France | Monetary policy and digital currencies: Much ado about nothing? | 5 | 2017 |
| Raskin & Yermack | National Bureau of Economic Research | Digital Currencies, decentralized ledgers and the future of Central Banking | 127 | 2016 |
| Rochon et al. | International Monetary Fund | Casting Light on Central Bank Digital Currency | 39 | 2018 |
| Skingsley | Sveriges Riksbank | Should the Riksbank Issue e-krona? | 62 | 2016 |
| Wadsworth | The Reserve Bank of New Zealand | Decrypting the role of distributed ledger technology in payments processes | 4 | 2018 |
| Wadsworth | The Reserve Bank of New Zealand | The Pros and Cons of Issuing a Central Bank Digital Currency | 6 | 2018 |
| Ward & Rochemont | Institute and Faculty of Actuaries | Understanding Central Bank Digital Currency (CBDC) | 1 | 2019 |
| World Economic Forum | World Economic Forum | Central Banks and Distributed Ledger Technology:<br><br>How are Central Banks Exploring Blockchain Today? | N/A | 2019 |
| Wu & Xia | National Bureau of Economic Research | Measuring the macroeconomic impact of monetary policy at ZLB | 930 | 2014 |

| | | | | |
|---|---|---|---|---|
| | | | | |
| Yao | People’s Bank of China | A systematic framework to understand central bank<br><br>digital currency | 9 | 2017 |

[1]The number of citations for each paper is based on what is reported on Google Scholar.

*Note:* N/A indicates that the information was not available, Based on Liston, 2011

# 4. CENTRAL BANK DIGITAL CURRENCY

Central bank digital currency (CBDC), also known as Digital Fiat Currency (DFC), Digital base money, or Central Bank E-money, is being investigated by a multitude of central banks all across the world. A survey conducted by Barontini and Holden in 2019 found that of 63 nations, 70 percent of the respondents were currently engaged in work on CBDC. The respondents represented about 80 percent of the world's population and approximately 90 percent of total economic output. The participants in the survey come from diverse economic backgrounds, with 41 emerging markets countries and 22 advanced economies (Barontini & Holden, 2019). The results raise the question of what a CBDC entails?

> CBDC is not a well-defined term. It is used to refer to a number of concepts. However, it is envisioned by most to be a new form of central bank money. That is, a central bank liability, denominated in an existing unit of account, which serves both as a medium of exchange and a store of value […]". (CPMI, 2018, pg. 3)

The International Monetary Fund (IMF) defines it as "a widely accessible digital form of fiat money that could be legal tender" (Rochon et al., 2018, pg. 4). Currency or, more specifically, money has gone through several stages of innovation throughout history. The barter system came first, followed by minted coinage, before the arrival of the gold standard, and finally, today's fiat currency came to be.

Therefore, it seems that CBDC might be the next stage of innovation. However, how would a central bank go about implementing this technology? What specific design features exist? What are the benefits related to a CBDC? Are there any issues associated with it? The next two sections consider these questions, but first, one needs to consider if a CBDC would fulfill the functions of money and if it would be an upgrade on today's legal tender.

## 4.1 MONEY AND THE MONEY SUPPLY

Money is a recognized medium of exchange for goods and services (Staff Author, 2019; Ward & Richemont, 2019). There are three main functions that money needs to fulfill: a unit of account, medium of exchange, and store of value. It means that virtually anything can be considered money as long as it accomplishes these three aspects (Rochon et al., 2018).

The history of money is described by Barry Eichengreen (2019) in his paper "From commodity to Fiat and Now to Crypto: What does history tell us?". It has ultimately led to the banking system that exists today, coined fractional banking, in which banks only hold a portion of customer deposits in reserve. Within this system, there are two types of money, central bank money, and commercial bank money.

Central bank money, otherwise known as fiat money, is government-issued, typically in the form of notes and coins, that is not backed by a commodity but rather the issuing government. As opposed to commodity-backed money, which bases its value on the underlying worth of an asset, fiat money derives its value from the supply and demand relationship and the stability of the government that issued it (Skingsley 2016; Ward & Richemont, 2019). In terms of the money supply, this depicts a form of money known as MB or M0.

Commercial bank money, on the other hand, is a form of money that is a claim on financial institutions that can be used to purchase goods and services. Fractional banking enables the creation of this class of money. The banks create account balances and make loans that have a considerably higher value than the underlying base currency that they hold (Skingsley, 2016). These account balances are held at the central bank and are used to facilitate electronic settlements through the use of Real-Time Gross Settlement (RTGS) systems. This money is a form of central bank electronic money, also known as central bank digital currency (wholesale) (Yao, 2018; Ward & Richemont, 2019). The money supply depicts this form of money as M1-M3.

Central bank digital currency (CBDC) would represent a stake on the issuing governments M0 money supply in a digital form, as opposed to the physical form that banknotes and coins now encapsulate (Skingsley, 2016). Compared to digital commercial bank money, it would be a more secure form of money, as the likelihood of a central bank defaulting on its debt is substantially lower than a commercial bank. It is within this definition that the authors consider the taxonomy, benefits, and issues associated with a CBDC. The valuation would depend on the credibility of the specific central bank, just as fiat currency now does (Berentsen & Schar, 2018).

However, first, one needs to consider whether central bank digital currency would fulfill the three functions of money.

## 4.2 THE FUNCTIONS OF MONEY

Stated above, the three functions of money are:

1. A unit of account
2. Medium of exchange
3. Store of value

A unit of account depicts price stability under all economic circumstances, and due to money being a public good, this is a requirement. This condition means that it functions as a "standard" of relative worth and deferred payment. A medium of exchange entails that money can function as an intermediary between goods and services. It needs to be universally accepted and verifiable while also being efficient. In short, it should be practically costless. Store of value requires money to be reliably stored, saved, retrieved and exchanged as a means of payment at a later date (Skingsley, 2016; Bordo & Levin, 2017; Rochon et al., 2018). Central banks play a crucial role in upholding the supply side of money and ensuring that fiat money fulfills these three functions. Current physical cash, such as the US dollar or the NOK, meet these criteria. The question is whether a CBDC can do so as well?

Given that it will function as a digital version of physical fiat currency, either through the use of a token or an account, it is safe to conclude that it fulfills the three functions of money (Rochon et al., 2018; Yao, 2018). However, will it be able to fulfill these functions equally well or better than the current physical currency?

### *4.2.1 CBDC as a stable unit of account*

Stability is a requirement for any form of money to function. With a CBDC, its design must not interfere with this goal. Depending on its presentation, as a complement or replacement for physical cash, the measurement of the value of goods should be consistent. Therefore, a CBDC would need to have a 1:1 ratio with the current M0 money supply and maintain the current value of fiat money (Raskin & Yermack, 2016). Bordo and Levin (2017) indicate that a stable unit of accounts helps to facilitate the financial and economic decisions of both individuals and businesses, for example, the determination of wages and prices. They suggest that since the prices on goods and services are set by businesses that operate in specific markets as opposed to a "central planner," it is only possible to achieve price stability through the appropriate setting of monetary policy. Most central banks today maintain positive inflation targets and are often limited to the ZLB when setting their policy rates. The reason for this is that if the rate is below this limit, people will hold physical cash, as opposed to keeping money in the bank (Rochon et al., 2018). If CBDC were to become the only form of legal tender within a country, the restrictions that are imposed by physical cash could be removed, thus making it possible to implement a rate below the ZLB. Therefore, this could make it possible to foster true price stability, which means that the value of a CBDC would remain stable over time in terms of a broad consumer price index (Bordo & Levin 2017; Yao, 2018). Consequently, this would make a CBDC a more stable unit of account than physical fiat currency.

### *4.2.2 CDBC as an effective medium of exchange and secure store of value*

For a CBDC to function as a medium of exchange, it must be universally accepted and efficient, all while it protects consumers and incurs a minimal cost to taxpayers. Milton Friedman (1960) highlighted that to work as an effective medium of exchange, government-issued money should carry the same rate of return as other risk-free assets (Bordo & Levin 2017).

Physical cash is not a very effective medium of exchange due to a variety of reasons. The first is due to the high transaction costs associated with it, given the need to meet in person or having to withdraw it from an automated teller machine (ATM) physically. This process could be especially tricky in more remote areas of the world (Raskin & Yermack, 2016; Rochon et al., 2018). A CBDC could limit these costs as transactions would not need to be carried out in person, and topping up a device on this form of money can be done through cloud-based solutions. Another reason is the vulnerability of theft linked to notes and coins and can be especially problematic when transporting large amounts (Raskin & Yermack, 2016; Rochon et al., 2018). Depending on a CBDC's design, the value will not be stored locally on a device and should be able to reduce this liability associated with physical cash. The final reason is due to the lack of returns that physical fiat currency offers (Raskin & Yermack, 2016; Rochon et al., 2018). This aspect ties back to the statement by Friedman about how government-issued money needs to offer some return to function as an effective medium of exchange. Technically, interest can be paid on this form of money, unless stored on a physical device, which means that the value is stored locally. This characteristic of a CBDC means that it will provide a more secure store of value than physical cash and be a more efficient means of payment (Bordo & Levin 2017).

## 4.3 TAXONOMY OF CBDC

There are two distinct variants of a CBDC, retail or wholesale. The former would function for the general public, and some describe this as a general-purpose CBDC. The latter is a restricted type of digital currency, which would be used by the commercial banks and the financial sector, for example, through interbank payments or security settlements. Both can be broken down further, into either an account-based or token-based variant (Barontini & Holden, 2019). Bech and Garratt (2017) created a Venn diagram, known as "The Money Flower," which illustrates four key properties of money; issuer (central bank or not), form (digital or physical), accessibility (widely or restricted), and technology (account-based or token-based). When discussing the topic of CBDC, this diagram will form the basis of this review (CPMI, 2018; Ward & Rochemont, 2019; Bech & Garratt, 2017; BIS, 2018; World Economic Forum, 2019)

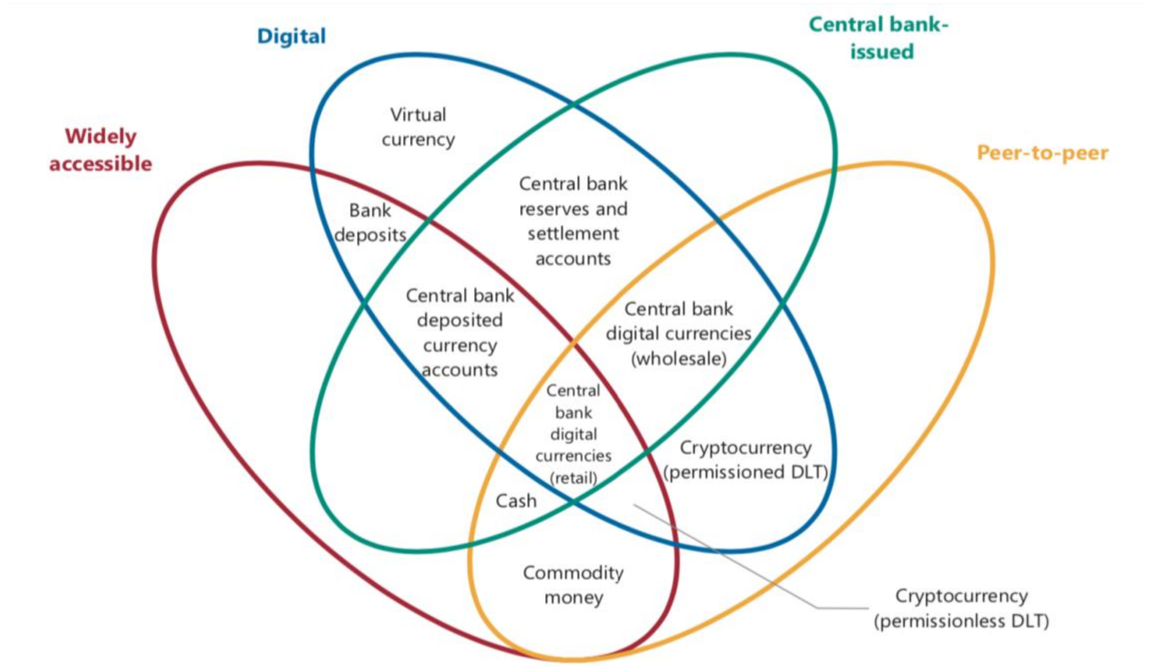


*Figure 2: The Money Flower: A Taxonomy of Money*

*Source: BIS 2018 pg. 94, adapted from Bech & Garratt (2017).*

The three types that are of interest for this thesis are the ones that are in the middle of the Venn diagram, depicted as central bank deposited accounts and central bank digital currencies (retail and wholesale). Central bank reserves and settlement accounts, also defined as an account-based wholesale CBDC, already exist and use RTGS systems, though central banks are also looking for ways to increase efficiency and security in these structures as well. The consideration of each type is in terms of the benefits and costs associated with these designs. According to the study conducted by Barontini and Holden (2019), of the respondents that said that they were currently engaged in CBDC research, 56 percent are engaging in both retail and wholesale variants, 13 percent are only considering retail types, and the rest are only looking into wholesale CBDC (Barontini & Holden, 2019). The central banks that took part in this survey showed that they were at different stages, ranging from research and experimentation to early implementation. There are currently considerations for CBDC usage in ten different cases (Barontini & Holden, 2019; World Economic Forum, 2019).

### *4.3.1 Design features*

A CBDC is said to have five critical design features that affect how it would work and what impact it could have: availability, anonymity, transfer mechanisms, interest-bearing, and limits and caps (CPMI, 2018; Rochon et al., 2018).

Table 3

*Key design features of central bank money*

| | Existing central bank money | | Central bank digital currencies | | |
|---|---|---|---|---|---|
| | Cash | Reserves and settlement balances | General purpose token | General purpose accounts | Wholesale only token |
| 24/7 availability | ✓ | × | ✓ | (✓) | (✓) |
| Anonymity vis-à-vis central bank | ✓ | × | (✓) | × | (✓) |
| Peer-to-peer transfer | ✓ | × | (✓) | × | (✓) |
| Interest-bearing | × | (✓) | (✓) | (✓) | (✓) |
| Limits or caps | × | × | (✓) | (✓) | (✓) |

✓ = existing or likely feature, (✓) = possible feature, × = not typical or possible feature.

*Source: CPMI, 2018, pg. 6*

*Availability*

Current accessibility to central bank money is limited to the central bank’s opening hours, typically five days a week and less than 24 hours a day. A CBDC could have 24/7 availability, or the central bank could decide only to have specified operating hours. This feature would depend on the technology used and the available resources that the central bank has (CPMI, 2018). Implementing a CBDC through the use of blockchain would open up for the possibility of having 24/7 access.

One also needs to consider if a CBDC should be available to the general public or only to financial institutions. Today there is one form of central bank money that is available to everyone, namely physical cash. If the ultimate goal of the central bank is to phase out the use of this form of money and transition into a “cashless society,” making CBDC widely accessible to the public would be the ideal implementation (Bordo & Levin 2017).

*Anonymity*

A CBDC could provide varying degrees of anonymity, depending on the issuing central bank's concerns regarding privacy. It also depends on how much one wants to curtail illegal financial transactions such as tax evasion, money laundering, and funding of terrorism. It will end up becoming a trade-off between user preferences for privacy and trying to reduce the risk associated with financial integrity (CPMI, 2018; Rochon et al., 2018).

*Transfer mechanism*

This aspect depends on whether one wants the transaction of a CBDC to be peer-to-peer or through an intermediary. A peer-to-peer manner would be viewed as a decentralized transfer mechanism as it occurs between two parties without the need for a central mediator. Using an intermediary, such as a central bank or another third party, would be considered a centralized transfer mechanism (CPMI, 2018; Rochon et al., 2018). Blockchain opens up for the possibility of either having a centralized or decentralized system.

*Interest bearing*

A CBDC would be considered a central bank liability, which means that it could technically be possible to pay interest. The central bank would set this interest rate, and it could be connected to existing policy rates or set at levels that either increase or decrease the demand for CBDC depending on the goals of the central bank. A CBDC could either have a constant nominal value, a stable real value, or be interest-bearing (CPMI, 2018; Rochon et al., 2018).

An interest-bearing CBDC would be ideal, as it could provide a secure store of value, though this is highly theoretical, and the real-world effects are unknown.

*Limits or caps*

The implementation of limits or caps on the amount of CBDC that can be held by any one individual or transferred between accounts could be beneficial to deter undesirable implications associated with this type of money (CPMI, 2018; Rochon et al., 2018). Such a measure could, for example, prevent potential digital bank runs. It can also be utilized to steer the usage of this money in a particular direction. Limits already exist on physical cash, in terms of the amount of money that one can potentially withdraw from an ATM (Pritchard, 2019).

### *4.3.2 Retail CBDC*

*Token-based*

In terms of the money-flower depicted above, central bank digital currencies (retail), also known as a token-based retail CBDC, is a central bank digitally issued widely accessible token-based type of money. This class of CBDC would circulate electronically in the economy between individuals and firms and is only rarely deposited back at the central bank (Bech & Garratt, 2017; Bordo & Levin, 2017). The central bank needs to be willing to buy/sell any number of these tokens at par, to ensure parity between these tokens and central bank reserves (Berentsen & Schar, 2018). This facet of token-based CBDC means that the central bank would control the supply of these tokens, meaning it is the only institution that can create ("mint") them. The tokens would serve as legal tender, fixed in nominal terms (Bordo & Levin, 2017).

Token-based CBDC would mimic certain design features of physical cash, as payments using this form of digital currency would represent the transfer of an object, in this case, a digital token. Transactions of this type would include more steps than exchanging cash but would offer the ability to avoid meeting in person. Given that it is the transfer of an object, it relies on the authenticity of the transferred token, not the individuals involved in the transaction (Kahn, Rivadeneyra, & Wong, 2018). Therefore, due to the complexity associated with token-based CBDC, the settlement of such transactions would require a form of external verification. This process increases the cost associated with this approach (Bordo & Levin, 2017). Verification implies that the amount of anonymity associated with such transfers would decrease. The validation of ownership of CBDC tokens and authentication of a transaction could be done using blockchain, which means that direct involvement from the central bank or another third party in this process would be unnecessary (Bech & Garatt, 2017). The extent of anonymity depends on the design features that the issuing central bank decides on using. It might be possible that the central bank would want a token-based CBDC to be similar to cash in terms of anonymity, which could be possible to a certain extent, though it will never be truly anonymous (Rochon et al., 2018). Depicted in figure 3 are the mechanisms of a token-based CBDC.

A CBDC in token form can be held in two ways, either stored on a physical device or using register-based solutions. With the former, the money will be stored locally on a physical device, for example, a mobile phone or payment card. The latter entails a connection between the money and an underlying registry (Norges Bank, 2019). The solution that a central bank decides on using depends on their goals and the different requirements within their country.

By using a physical device, the value will be stored locally, conducting payments through a transfer of funds between the devices of the parties involved. Cryptographic technology would most likely be used to ensure the integrity of the value. However, payments would need to be conducted in a peer-to-peer fashion, most likely close to one another. For example, this can occur between the device and a card reader or through using QR codes. These settlements would happen immediately and would be final. The payer in such a system would not have to identify themselves, but the transaction registers to the device used — this process means that when adding funds, one could tie the device to an individual. Norges Bank (2019) highlights adding further anonymity by giving people the possibility to top up their device using cash. A significant downside to this token-based CBDC is that once the device is lost or destroyed, the money is gone. This limitation means that a limit or cap would most likely need to be enforced to deter people from placing all their funds on these devices. Finally, it would not be possible to pay interest, as the value is stored locally, much in the same fashion that physical cash does not earn interest (Norges Bank, 2019). Therefore, it will have a constant nominal value.

A register-based solution requires the establishment of a register that would record all transactions, similar to current bank ledgers. This solution would not be connected to any physical device, but rather through a user interface connected to the register (Norges Bank, 2019). It could, for example, be a mobile application. This measure avoids the double-spending problem and makes sure that the money used in a transaction is available. It would be similar to a bank account, but instead of linking particular identities to the register, it would use cryptographic keys and codes. This feature would decrease the amount of anonymity associated with this method, though uncovering someone's identity based on these keys and codes would be highly unlikely. This principle is essential in all cryptocurrencies and would ideally be implemented using blockchain (Norges Bank, 2019). Wandhofer (2017) argues that distributed ledger technology (DLT) is the most suitable implementation of a CBDC. ApplePay is similar to this type of token-based CBDC. This type of token-based CBDC could technically pay interest, as the value of the token is not stored locally.

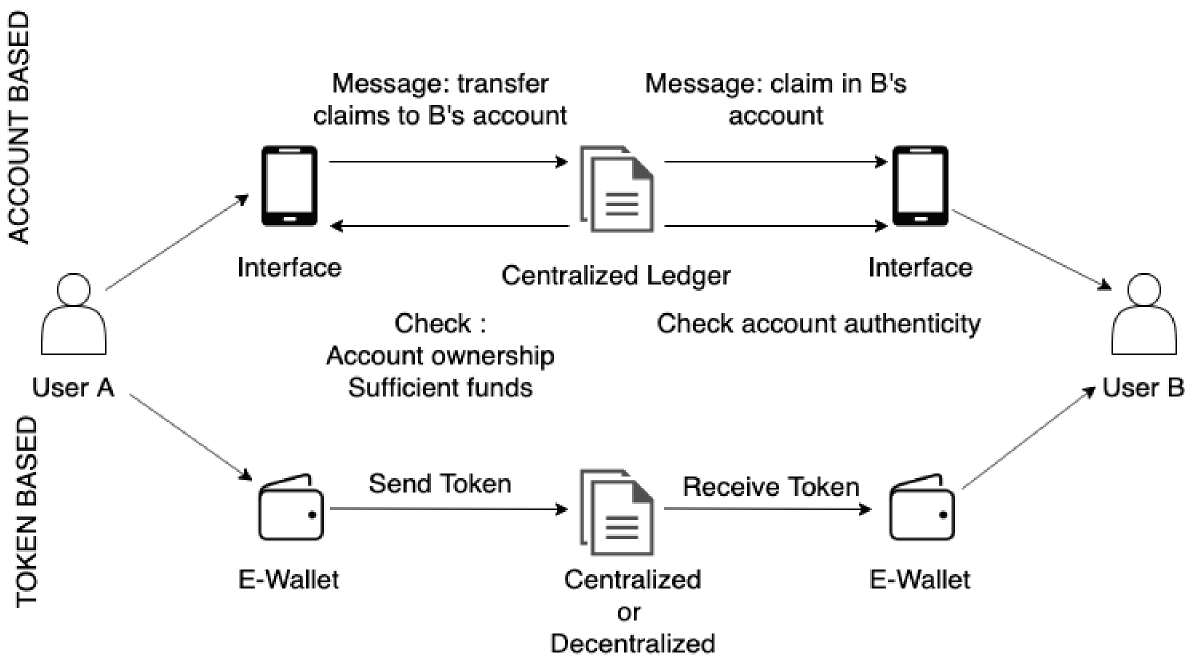


*Figure 3: Account- and token-based CBDC: Basic mechanics*

*Based on Rochon et al., 2018, pg. 10*

*Account-based*

In terms of the money flower depicted above, central bank deposited currency accounts, also known as account-based retail CBDC, is a central bank digitally issued widely accessible account-based type of money. This class of CBDC is analogous to debit cards, given that people would hold electronic accounts at either the central bank or at supervised depository institutions (Bordo & Levin, 2017). With this approach, each payment would be completed by debiting the account of the payor and crediting the payee's account. The value linked to the credit balance connects to a specific account, which links to a particular identifiable account holder (Norges Bank, 2019). Figure 3 presents the mechanisms for this method.

This form of retail CBDC has a crucial advantage over its token-based counterpart in terms of payments. It is pretty much instantaneous and cost-free. However, this comes at a price. When creating these accounts, verifying the identity of the account holder happens by showing a form of legal ID, meaning that the level of anonymity would decrease. This process would be similar to opening a bank account today. However, when this identification process has happened, it would technically be possible to hide people's identity, especially from third parties that might be interested in data concerning individuals' payment history (Yao, 2018). However, this approach will tend to have less anonymity associated with it than a token-based solution. The central bank would still be able to monitor any unusual activity and could implement an anti-fraud mechanism through the use of smart contracts. This class of CBDC could, from a technical standpoint, pay interest (Bordo & Levin 2017).

Dyson and Hodgson (2016) and Bordo and Levin (2017) highlight two types of account-based CBDC. One could either hold an account directly with the central bank or indirectly via specifically designated accounts at supervised commercial banks or private institutions.

A direct access approach would be reminiscent of the early years of central banking, abandoned due to the sheer amount of bookkeeping that was needed when the number of private accounts increased. However, due to the altering landscape of technology, with innovations in data storage and high-speed network capabilities, this type of account-based CBDC could now be possible (Bordo & Levin 2017). The central bank of Ecuador implemented its own CBDC, known as dinero electrónico, or DE, which used this approach. Unfortunately, it has since been considered a failure and abandoned in 2018 (White, 2018). The Bank of England pointed out that this solution would be a massive administrative undertaking. It could also alter the perception of the central bank from being the overseer of commercial banks to just another entity in the banking sector (Dyson & Hodgson, 2016).

Through an indirect access approach, the central bank would still control the money supply, but private sector firms would conduct payments and customer service. Adrian and Mancini-Griffoli (2019) call this solution synthetic CBDC. This model is outlined in the paper "Increasing Competition in Payment Services" by Dyson and Hodgson (2014), where either banks or technology companies would provide accounts known as "Digital Cash Account" (DCA), and these companies would be known as "DCA providers." Tobin (1987) refers to these forms of accounts as "deposited currency accounts" (DCAs). The "DCA providers" would have a host of responsibilities, including mobile banking and customer service, so that holders of digital fiat currency would be able to use it similar to current bank accounts. This approach has considerable advantages over a direct access model. It would minimize the burden placed upon the central bank, outsourcing tasks to other companies that would be superior in areas of payment services, user interfaces, and customer service (Adrian & Mancini-Griffoli, 2019). It would be a market-driven approach, as firms tasked with implementing this CBDC would be encouraged to innovate to maintain their customers and market share. This process could be a more viable option for smaller banks that focus on "relationship banking" (Bordo & Levin, 2017).

Norges Bank (2019) discusses two slightly different alternatives for an account-based CBDC. They are open or closed account solution. An open account solution would bear similarities to accounts that are offered by private banks. With this solution, direct transactions can take place between people with accounts in different banks. A closed account solution would have similarities to private e-money, where all parties in a transaction would need to have an account with the central bank. Another name for this approach is "account-based solution with restrictions" (Norges Bank, 2019).

### *4.3.3 Wholesale CBDC*

In terms of the money flower, central bank digital currencies (wholesale), also known as a token-based wholesale CBDC, is a central bank digital issued restricted token-based type of money. For a token-based CBDC, one also has the option to have a decentralized or centralized scheme (Kahn et al., 2018). Most central banks indicate that the central bank should issue a wholesale CBDC as this would remove credit risk and ensure the stability of the token (OMFIF & IBM, 2018). The main reason to implement this type of CBDC is to improve efficiency and the reduction of settlement costs (Bech & Garratt, 2017).

A token-based wholesale CBDC would work in a peer-to-peer fashion, transferred through the use of a distributed ledger, but would only be available to specific financial institutions. The token would be a bearer asset and value-based, meaning that the value would be transferred from the payor to the payee, without an intermediary. This type of CBDC could work as a complement to reserves at the central bank, or it could replace it altogether (De Meijer, 2019). The difference between a retail and wholesale token is that wholesale payments do not offer cash-like anonymity. This tokenized solution could give a degree of anonymity, depending on whether it uses a centralized or decentralized structure. If one uses a decentralized system, the need for a central operator to be online would be unnecessary. As long as the participants, in this case, financial intermediaries, remain online, they can continue to send tokens peer-to-peer and settle central bank money in real-time. Current central bank reserves are only accessible during central bank opening hours or specified hours. It could be possible to set up a secondary market for token-based CBDC that could operate outside of these hours, and primarily through the use of a decentralized system (OMFIF & IBM, 2018).

Central banks already use deposit and base rates to affect interbank activities. In essence, this concept can transfer to a wholesale CBDC, which can be interest-bearing. The rate on the tokens could be used similarly to existing rates in interbank transactions. Additionally, smart contracts could also increase the simplicity and functionality of different processes, given that there are mutual agreements and execution code for multiple tasks contained within the blockchain. The possibility for this could increase the utility of this form of money (OMFIF & IBM, 2018).

The tokenization and recording of financial assets on a distributed ledger can reduce the operational risks and running costs due to productivity gains. A wholesale CBDC would be able to do this. Financial assets typically move through the exchange of money, reconciling this movement on two separate ledgers by the parties involved. Due to this, settlement and operational risk increase. The central bank could issue a token-based wholesale CBDC and record it on a blockchain to reduce these risks (OMFIF & IBM, 2018).

At the present moment, the attention of most central banks is on the application of DLT in RTGS and the increase of cross-border interbank settlements. These systems maintain the continuous process of settling payments on an individual order basis without bundling transactions together on the balance sheet of the central bank. The process of settling payments happens at the end of the day and are final (Daugherty, 2019). The main interest in applying DLT in RTGS is due to these systems coming towards the end of their technological life cycles. The design of the databases is outdated, and the programming languages used are obsolete (De Meijer, 2019). Current RTGS systems only record cash, but due to most business transactions involving the movement of both money and assets, this complicates the process. By using a blockchain, the transaction of any asset, be it equities, bonds, or derivatives, can be recorded, allowing for multiple, simultaneous changes to the ledger. Therefore, the token can be part of an atomic transaction, where there are several simultaneous changes to the ledger made across multiple assets. This process connects the full and final settlement of money with the movement of an asset (OMFIF & IBM, 2018).

# 5. MOTIVATIONS AND CONCERNS FOR CBDC

## 5.1 WHY ISSUE A CBDC?

There seems to be a general movement towards CBDC from central banks, with a myriad of reasons for why they would be interested in this new form of currency. The survey referenced earlier conducted by Barontini and Holden (2019) found that the most important motivator for implementing a digital currency was payment safety and domestic efficiency. For wholesale CBDC, financial inclusion was the least important factor, while cross-border payment efficiency was ranked the lowest for retail CBDC (Barontini & Holden, 2019). There were also marked differences between central banks in advanced economies and emerging markets. A survey conducted by OMFIF and IBM found that the majority of respondents' primary motivator for pursuing a wholesale CBDC was the potential to improve speed and cost-efficiency (OMFIF & IBM, 2018). They also issued a survey on the motivations for a retail CBDC, where respondents indicated that maintaining competitive payment systems and enabling better anti-laundering enforcement were essential reasons (OMFIF & IBM, 2019). There are several reasons for why central banks would want to issue a CBDC, and this section considers the majority of them.

### *5.1.1 Ensure legal tender availability*

The availability of legal tender is essential as it is a legally recognized form of payment that represents a claim on the central bank/government. If two parties conducting a transaction are at an impasse in terms of the payment method, a legal tender will always be a viable option for settlement. Therefore, the introduction of a CBDC could ensure that the public has access to a legal medium of exchange if cash were phased out. Cash usage in transactions, especially in countries like Norway and Sweden, has been steadily declining over the past years as the ease of conducting payments through cards, mobile applications, and contactless have increased. An analysis conducted by Worldpay and OMFIF found that cash usage at point-of-sale will decline over the next four years.

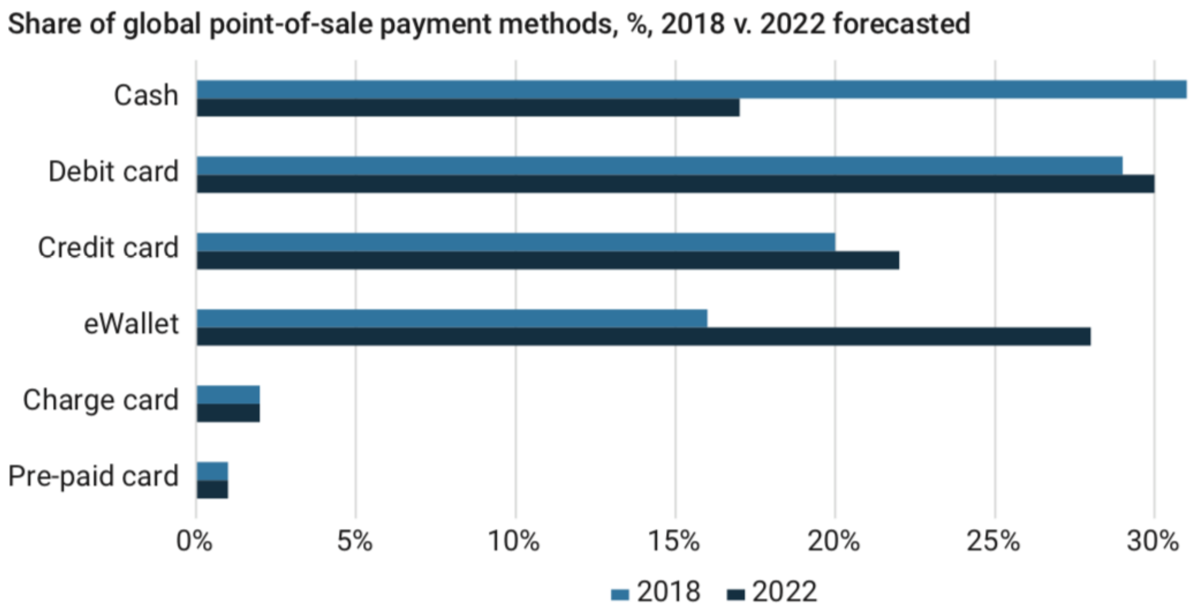


*Figure 4: Expected change in payment methods over the next four years*

*Source: OMFIF & IBM, 2019, pg. 13*

Nevertheless, it is unlikely that a central bank would remove cash from circulation, though this could depend on the government's objectives. Cash has negative characteristics associated with it, such as the difficulty related to tracing notes and coins, which makes it attractive for tax evasion, money laundering, and illegal transactions. It also poses significant security risks when transporting funds, and when conducting payments, without establishing any record of exchange. Therefore, a future government could wish to eliminate cash from the money supply to reduce crime and improve tax income (Ward & Rochemont, 2019). This possibility means that the central bank could facilitate the gradual elimination of cash from circulation by making a retail CBDC widely available (Bordo Levin, 2017).

### *5.1.2 Efficiency gains*

Discussed in Chapter 4, a CBDC could be a practically costless medium of exchange, which means it could significantly improve the efficiency of the current payment system. Bordo and Levin (2017) argue that this will primarily impact lower-income households as well as small businesses. The reason for this is due to them being heavily reliant on cash, and therefore incur the costs associated with handling physical fiat-money. For example, at some ATMs, consumers have to pay between two to five percent or more in fees, while retail businesses acquire costs associated with sorting, cleaning, and verification of cash, as well as fees associated with debit and credit cards. A CBDC could eliminate most of these costs (Bordo &

Levin, 2017). Barrdear and Kumhof (2016) analyzed a dynamic stochastic general equilibrium model of the United States economy and found that the adoption of CBDC raised real GDP by about three percent. The production of notes and coins and their storage also reduce efficiency within a country. In April 2017, the Bank of Korea conducted a coinless society trial, which allowed customers to deposit change onto prepaid cards as opposed to accepting the small change from purchases. Given that South Korea spent nearly 53.7 billion Won, approximately 36.7 million pounds sterling in 2016 on producing coins, this initiative could have significant cost-saving benefits (Ward & Rochemont, 2019). A CBDC could display similar advantages.

### *5.1.3 Competition from private money*

The rapid pace of recent and prospective innovations in payment technology such as the cryptocurrency market, Facebook's Libra initiative, and other private e-money can end up making them major contenders with central bank-issued fiat money within the next few years. If these private monies gain a large enough user base, it could affect central banks' ability to control the money supply, conduct monetary policy, and maintain financial stability (Bordo & Levin, 2017). For example, if governments were to issue social welfare using fiat currency while privately issued e-money has a monopoly on payments, this could incur social welfare costs. The benefits citizens receive could also be affected. Another issue associated with private money is that companies who provide this service are focused on maximizing their profits. Therefore, their incentives would not align with the purpose of fiat currency (Ward & Rochemont, 2019). In light of such considerations, it seems sensible that many central banks are considering the introduction of a CBDC to combat these concerns. A CBDC, as opposed to physical cash, would likely work in greater unison with the rapid developments in technology and could assist the central bank in maintaining control over the money supply (Bordo & Levin, 2017). Finally, a CBDC does not need to try and monopolize the payments market, but could instead work as a complement to the services provided by private entities. A CBDC could ensure that quasi-monopolies did not surface in this market (Bordo & Levin, 2017).

### 5.1.4 Improve cross border payments efficiency

Domestic payments have, over the past two decades, become more rapid and efficient. In many countries, there is 24/7 access provided with minimal settlement time. However, the development in cross-border payments has been much slower, as they remain cumbersome, expensive, and slow. Sixty-two percent of the respondents in OMFIF and IBM's survey indicated that an introduction of CBDCs in several different jurisdictions could help to improve these types of payments. It would do this by reducing the reliance on costly correspondent banking networks and pre-funded accounts (IBM & OMFIF, 2018). A joint study conducted by the central banks of Canada, the United Kingdom, and Singapore looked into the potential for a CBDC to improve counterparty credit risk for cross-border interbank payments and settlements. However, it only looked at a wholesale version of CBDC. The findings were that a jurisdiction-specific wholesale CBDC exchanging only across borders offered little benefit over existing models using RTGS. Nonetheless, it could improve counterparty credit and payment and settlement risks, and a universally accepted wholesale CBDC could significantly improve these aspects as well. The benefits were also 24-hour availability and higher anonymity (Ward & Rochemont 2019).

### 5.1.5 Ensuring financial stability

Financial stability could improve through the use of a CBDC for several reasons. The financial system in many nations features highly leveraged banks, where liquidity and maturity transformation is at the core of the payment system. The commercial banks' issue claims (commercial bank money) used as both a medium of exchange and as a store of value. These claims are known as "inside money" and can be relatively unstable when presented with adverse negative externalities in the economy. A CBDC ("outside money"), depending on its design, would be used as a medium of exchange and store of value and could reduce the overall risk of the financial sector. This characteristic is due to a CBDC being virtually risk-free. A possible shift from bank deposits to CBDC could also have an impact on bank funding and credit provisions, which also affect stability (OMFIF & IBM 2019). If a CBDC were designed to be interest-bearing, and on top of this paper currency was eliminated, more advanced monetary policy could also be employed. This design could remove the constraints of ZLB, and the "inflation buffer" could also be disregarded (Bordo & Levin 2017).

### 5.1.6 Increase seigniorage revenues

Seigniorage is an integral part of a central banks' budget. Studies conducted by the Bank of Canada found that as the usage of cash declines, some central banks have seen their seigniorage revenues dwindle (Ward & Rochemont, 2019). A similar problem is faced by countries that have adopted a foreign currency (usually the US dollar) as their domestic means of exchange, foregoing potential revenues. A CBDC could be a way for economies where the US dollar is the main currency to recapture some seigniorage, while advanced economies could boost their revenues (OMFIF & IBM 2019). This effect depends on the design decisions of the CBDC. For a dollarized economy, a CBDC could offer a means of regaining greater control of its domestic monetary system. The Marshall Islands is one such economy, and are currently developing a digital currency called "Sovereign," as they attempt to regain monetary sovereignty. However, 66 percent of respondents in OMFIF and IBM's study believe that a CBDC will have minimal impact on seigniorage, and further research is needed to understand the effects fully (OMFIF & IBM 2019).

### 5.1.7 Discourage tax evasion, money laundering, and other illegal activities

The widespread use of a CBDC combined with the obsolescence of paper currency could be beneficial in discouraging illegal activities such as tax evasion, money laundering, and terrorist funding. The benefit is likely substantial in advanced economies, but even more so for emerging ones where large fractions of economic activity are done with cash, leading to high incidences of tax evasion. Depending on the design of a CBDC, small transactions can be conducted relatively anonymously, while more substantial transactions would need to have a verified identity connected to it (Bordo & Levin 2017). If a CBDC takes a token-based form, with cash-like offline payment possibilities, tracing would be difficult. However, there are existing regulations that could find a credible balance between anonymity and traceability. These are rules governing card payments, which are required by the European money laundering directives that limit this risk and could apply to a CBDC. In a broader sense, replacing cash with cash-like CBDC could help the authorities to perform anti-money laundering measures and combating illegal activities (OMFIF & IBM 2019).

### 5.1.8 Enhance the competitiveness of the banking system

With the introduction of an interest-bearing CBDC, the competitiveness of the banking system could improve. Bordo and Levin (2017) indicate that institutions that engage in "relationship banking" would likely not be affected. However, other less-competitive institutions might lose their deposits as the option for shifting funds to CBDC is made possible (Wadsworth, 2018b). It would also provide an alternative to banknotes, debit and credit cards, cheques, and other physical payment methods. Therefore, contestability in retail payments could increase, and since using CBDC for large-value transactions amongst banks and corporations is possible, it could provide more competition in the wholesale payment industry. By implementing the before-mentioned currency, it could facilitate access to the central bank's balance sheet for a wider variety of intuitions. This access could, in turn, make it easier for firms to enter the payments market, which would increase competition (Engert & Fung, 2017).

### 5.1.9 Improving financial inclusion

The IMF and BIS indicate that financial inclusion is one of the primary motivators for emerging markets and developing nations (Rochon et al., 2018; Barontini & Holden, 2019). This benefit is specifically for a retail CBDC. The World Bank indicates that 1.7 billion people are unbanked, wherein they do not have access to a commercial bank or account, mostly in developing countries (Demirguc-Kunt, Klapper, Singer, Ansar, & Hess, 2017). Retail CBDC could promote the digitization of these economies and, thus, social and economic development (Shirai, 2019). There is a view that financial inclusion is an essential way of reducing poverty, as bank accounts are vital in expanding businesses and making transactions more efficient and secure (Adrian, 2019). There are other ways of achieving this type of inclusion without the use of CBDC. The M-Pesa in Kenya and the Modelo in Peru are such payment mechanisms that increase inclusion without relying on CBDC. For most advanced economies, financial inclusion is not a noteworthy problem. In 2014, 94 percent of adults in high-income OECD nations said that they had bank accounts. Therefore, financial inclusion through a CBDC is of greater interest to emerging economies (Hodgson, 2017).

## 5.2 KEY FEASIBILITY AND OPERATIONAL CHALLENGES

Central banks have indicated several reasons for why they are interested in the exploration of CBDC. However, they are still cautious about the effects that it could have. In the short term, over 85 percent of central banks indicate that they are unlikely to issue any CBDC (Barontini & Holden, 2019). The initial exploration and experimentation by various central banks have identified several legal, technical, and operational issues that need consideration before a CBDC could be deemed suitable for wide-scale use.

### *5.2.1 Legal considerations*

In certain countries, there are specific legal considerations. In Barontini and Holden's (2019) survey, about a quarter of central banks indicated that they have the legal authority to issue a CBDC, while one third said that they did not, with the rest disclosing that they were unsure. Therefore, the authority to issue a digital currency and expand account access is not something that all central banks possess. The legal issues also depend on the design characteristics of the CBDC. Even though central banks are usually given the sole right to print legal tender, the issuance of a digital currency could require legislative changes that, at least in the short term, could be infeasible (CPMI, 2018). Few nations have written specific legislation on cryptocurrencies and blockchain technology that pertains to their asset class and how they are defined. For this reason, it could prove to be a hurdle to the implementation of this technology. Switzerland is one of the few countries that have taken a proactive role in this regard and has slowly been revising its legal structure (Haeberli, Oesterhelt, & Wherlock, 2019).

### *5.2.2 Anti-money laundering and combating the finance of terror concerns*

Current cryptocurrencies provide a sufficient way of conducting money laundering and financing terrorism. The current structure makes it practically impossible to track the identity of the parties involved in a transaction and could be of significant concern when introducing a CBDC based on the same technology (Malik, 2018). Therefore, it is essential that central banks take into account anti-money laundering and combating the financing of terror concerns and requirements when issuing a CBDC. These considerations are especially tricky if this class of money is introduced using blockchain, which is often notoriously linked with anonymity (Wadsworth, 2018b). As such, there is a reputational risk to the central bank associated with the issuance of a retail CBDC. However, depending on its design, these issues can be largely mitigated, but they must be considered at length when determining the ideal implementation of a CBDC (CPMI, 2018).

### *5.2.3 Privacy concerns*

A CBDC would most likely be a complement to physical cash before it ultimately led to the obsolescence of notes and coins in the future. However, cash does offer a couple of things that a CBDC will likely never be able to. Current physical fiat money gives users full anonymity, which is potentially a desirable feature that could be sorely missed by certain people (Rochon et al., 2018). Of course, limiting anonymity does reduce the probability of cash use in illicit activities, which could, as a whole, benefit the economy. However, according to Rogoff (2016), such behavior can also be deterred through the elimination of high denomination currency (McAndrews, 2017). The central bank and commercial bank deposits typically also provide some level of privacy. With the possible introduction of a CBDC, central banks need to consider the appropriate degree of privacy, judged in terms of the societal and digital environment. This consideration would take time and could include many challenging public policy design choices for a central bank (CPMI, 2018).

### *5.2.4 Cyber security*

Cyber-security is already an essential operational challenge for central bank systems and the financial industry as a whole. Cyber-threats, such as malware and fraud, are risks for almost every payment, clearing, and settlement system. For retail CBDC, they pose a particular challenge, as this system would be open to a lot of different people and could, therefore, open up for many points of attack (Wadsworth, 2018b; CPMI, 2018). By implementing this class of money through the use of blockchain, one can mitigate some of these effects, though the transaction speeds associated with this have been historically slow. Moreover, there is a substantial possibility that fraud could be significant due to the ease with which one can transfer large amounts of funds electronically. Therefore, limits or caps could be introduced to try and diminish some of this effect. Given that CBDC would be entirely dependent on electronic technology, any malfunction in this structure would be catastrophic. Massive power outages or incidents such as the Carrington Event, which was a solar storm that occurred in 1859, would likely render a CBDC useless, as all electronics would be knocked out (Wadsworth, 2018b). The central bank could account for this by storing physical cash as a backup strategy if such events were to occur. Therefore, maintaining high cybersecurity should be a prerequisite for CBDC issuance (CPMI, 2018).

### *5.2.5 The central bank overstepping its role*

The central bank focuses on maintaining stability within the financial sector, and it is the overseer of commercial banks. The introduction of a CBDC could potentially lead to the central bank overstepping this role (CPMI, 2018). As discussed above, digital currency could raise the contestability of the payment market, but an interest-bearing CBDC could be in direct competition with commercial banks. This change would limit the number of deposits that banks receive, which are a leading source of income, as people could shift their funds into CBDC, viewing this as a safer investment. This influx of deposits would also alter the banking structure from fractional to narrow banking (Wadsworth 2018a; CPMI, 2018). The implications of this are unknown. The central bank's balance sheet would increase, which could destabilize the central bank and raise the likelihood of default. Therefore, the design of a CBDC must uphold the mandate and structure of the central bank, without the need for a massive overhaul (CPMI, 2018).

### *5.2.6 Unknown factors*

The application areas of blockchain and a CBDC are still highly debated, and the robustness of this technology in ensuring a sound risk management framework is somewhat uncertain. Central banks and the services that they provide are essential to the smooth functioning of the economy. Therefore, the requirements for innovations in this sphere are that they uphold this efficiency through the implementation of technologies that are reliable, scalable, throughput, and resilient (Wadsworth 2018a; Bordo & Levin 2017; CPMI, 2018). The proposed CBDC with the use of blockchain is relatively untested, and even in the private sector, the investigation into the application areas of this technology is still in an early phase. The Bank for International Settlement (2018) point out that there are still many questions that need to be answered surrounding operational risk management and governance with CBDC. Many central banks also highlight that the maturity surrounding distributed ledger technology is highly questionable. Finally, many of the possibilities a CBDC could open up for in terms of monetary policy are theoretical, and their practical effect is unknown (CPMI, 2018). Therefore, it is hard to make any definitive conclusions in this area.

# 6. EFFECTS ON MONETARY POLICY

The primary tool for any central bank to maintain stability in the financial system is monetary policy. Raising or lowering the interest rates changes the money supply and in turn, the inflation and growth in the economy. Most central banks have a mandate to keep inflation at a predetermined level. If the current inflation is higher than this level, the central bank will raise the interest rate to slow down growth and in turn, inflation. In the opposite scenario, where the central bank sees the need for higher growth, interest rates will be lowered to stimulate the economy. In the last decade, Japan and multiple western European countries have experienced periods of low growth, even with historically low-interest rates. Why is it not working? The reason might be because of limitations to the current system due to the ZLB.

## 6.1 ZERO LOWER BOUND

### *6.1.1 Traditional view*

The ZLB is a problem that occurs when the short-term nominal interest rate is close to zero, and due to the nature of fiat-money, it limits the central bank's ability to stimulate the economy. Therefore, central banks have had to explore other options. The Federal Reserve has used large-scale asset purchases and forward guidance in the United States as an alternative in such a situation. Wu and Xia (2014) have measured the macroeconomic impact of monetary policy at the ZLB. They found that the effective federal base rate does not carry much information at the ZLB, while forward guidance, on the other hand, seems to have a small effect, though not statistically significant at the 10 percent level. The researchers devised a shadow rate that could be substituted for the base rate to measure the effects of monetary policy when this rate drops below the ZLB. The findings illustrated that when the shadow rate dropped below zero percent, it stimulated the economy, which supports the argument that a negative interest rate could be beneficial in such circumstances.

Hamilton and Wu (2011) explore the possibilities for alternative options for monetary policy when the short-term interest rate is at the ZLB. One option is for the central bank to communicate their commitment to reverse any decrease in the price level, and in turn, embrace the higher future inflation rates to achieve this. Although this works in theory, previous incidents of the Federal Reserve using this strategy have shown that the expectations are more challenging to control in practice. Another option is for the central bank to commit to buying assets, known as QE. However, this is considered an unconventional policy. There have been comprehensive empirical studies of such a measure that has provided an assessment of its effectiveness. Auerbach and Obstfeld (2003) investigated this topic with regards to the situation in Japan, where the ZLB constrains them and conclude that the quantitative operations conducted by the Bank of Japan were effective when carried out aggressively. They also point to the United States during the Great Depression as an example of monetary expansion working.

The negative interest rate could alleviate some of the problems central banks face today. Given that central banks have traditionally used interest rates to stimulate the economy, it is arguably better to use this method instead of QE. Jobst and Lin (2016) show the positive effect of negative interest rates on the economy by lowering the funding costs of banks and boosting asset prices. A common concern when lowering the base rate is the financial health of the banking sector. Jobst and Lin (2016) argue that a higher lending volume balances out lower margins, but the limit to how far the interest rate can drop is unclear. Therefore, they suggest using credit easing measures in correspondence with this to mitigate risks to banks' profitability. Arteta, Kose, Stocker, and Taskin (2016) also concluded that negative interest rates add monetary stimulus to the economy while also highlighting the potential threat this poses to the financial health of the bank industry.

### *6.1.2 The effect of a CBDC on the ZLB*

There are clear limits to current monetary policy due to the nature of cash, which in turn has prompted central banks to use unconventional strategies such as QE. While traditional fiat currency is constrained to this ZLB due to its physical form, a CBDC that is entirely digital could, in theory, introduce more flexibility for the central bank's monetary policy, effectively bypassing the current ZLB.

Bordo and Levin (2017) studied the impact of a CBDC on central banks' monetary policy. By designing the currency as interest-bearing, the interest rate would no longer be constrained by the ZLB in the event of an adverse shock. This claim is supported by Dyson and Hodgson (2016), who also point to the fact that physical cash would need to be removed from the economy for this to be effective. However, they argue that circumventing the ZLB is not the most persuasive argument for a CBDC. The Norwegian central bank supports this stance (Norges Bank, 2018a). The reason for this is not only due to other alternatives, but because the complete removal of physical cash in short to medium term would be difficult. One possible solution is increasing the cost of cash, which could make a CBDC effective even without the removal of notes and coins. In this circumstance, cash only needs to be more expensive to hold than the cost of negative interest rates.

Engert and Fung (2017) argue that increasing the friction of holding large amounts of physical cash would be sufficient to overcome the ZLB, and introducing a CBDC would not be needed. They share the view of Dyson and Hodgson (2016) and conclude with the idea of issuing a CBDC to overcome the ZLB not being a compelling argument.

Removing the ZLB has been considered as an alternative to the use of QE by Goodfriend (2000) and Buiter (2009), amongst others. In theory, a CBDC could move the ZLB, but the findings conflict in terms of how effective it would be as a tool for monetary policy. The extent to which it would be useful is determined by how far the central bank could push the interest rates into negative territory. Lowering the interest rate below the ZLB has never been done before. Therefore, there is uncertainty concerning the possible effects it can have on commercial banks and their operating margins. Based on the work of Wu and Xia (2014) and Hamilton and Wu (2011), lowering the ZLB should provide the central bank with an additional tool, even though some believe that this is not a compelling argument for a CBDC. However, a new tool might be beneficial for the central bank. There is little doubt that a CBDC would let central banks introduce a negative interest rate in cases of shocks, but the effectiveness is determined by how efficient moving the ZLB would be. Nevertheless, a CBDC could do more than affect the interest rate.

## 6.2 HELICOPTER MONEY

Many question marks surround the lowering of the ZLB, which means there needs to be a consideration of more unconventional methods. QE has proven to be an effective alternative, but there are side effects associated with this method. It lowers the yield on bonds, and pushing this yield even further down could prove to have a limited effect. The loudest critics of this monetary policy believe QE is fueling a bubble in the stock and bond markets. Dyson and Hodgson (2016) point out that QE benefits those who hold stocks and bonds, which is often a small fraction of the public. Therefore, using QE might not be as effective at stimulating the entire economy.

In “The Optimum Quantity of Money” from 1969, Friedman envisions a bird flying over a community, dropping money to the people. This thought experiment explored the results of a “one-off” increase in the money supply. The term was once again introduced by Ben Bernanke in 2002 and is now known as helicopter money. Instead of changing the balance sheet of the central bank, it would be a one-time distribution to citizens. Traditionally, the proposal to do this has been through crediting people’s bank balances or as a tax rebate (Gilbert, 2019). A CBDC based on a blockchain could introduce another mechanism for distributing the helicopter money.

A CBDC could serve as an efficient tool for distributing such cash. It would be an effective distributing mechanism, and as Dyson and Hodgson (2016) highlight, it benefits every member of society. Another benefit is the directness of helicopter money. While QE increases the prices of stocks and bonds, helicopter money increases the cash available for everyone to use, which directly affects spending. They advocate for the use of a CDBC as the current system is not constructed for this task. If the central bank were to issue helicopter money through commercial banks, it would increase their reserves, earning interest and increase the deposits which are close to interest-free, effectively giving the bank’s risk-free money. Since the central bank would have to pay interest on the reserve deposits, it would be no different from QE. Engert and Fung (2017) believe this can be done electronically in most modern countries. However, they have not addressed the concerns of the impact it would have on the current system, as Dyson and Hodgson (2016) did.

Helicopter money might seem like an extreme and unconventional policy, but it could be precisely what central banks need. Instead of trying to stimulate the economy by increasing loan activity, they can directly stimulate the spending of consumers. Although some might hold onto the newly distributed money, it would most likely effectively stimulate the real economy. It seems unlikely that the traditional system could handle such a policy efficiently. A CBDC implemented through an account- or register-based solution could provide a useful distribution mechanism. Blockchain technology could make it even more robust as any attempt at fraud would be close to impossible. Through the blockchain verification process, the amount deposited to each account would be done safely and securely, effectively eliminating any possibility of fraud.

## 6.3 INFLATION

Central banks use inflation-targeting as a means to maintain price stability. This strategy has resulted in aggregate price level following a random walk with upward drift because most central banks aim at two percent inflation without placing any weight on previous deviations from this target. Figure 5 shows the targeted and actual inflation in the US over the last two decades. Through a CBDC, the central bank could use price-level targeting that can fluctuate in the short term, while monetary policy can ensure that the price level returns to the target over time. This target would serve as a nominal anchor lowering the uncertainty associated with inflation targeting. These effects reduce the need to use unconventional measures like QE. Bordo and Levin (2017) highlight this benefit of a CBDC and the positive effect this could have on lower-income households and small businesses.

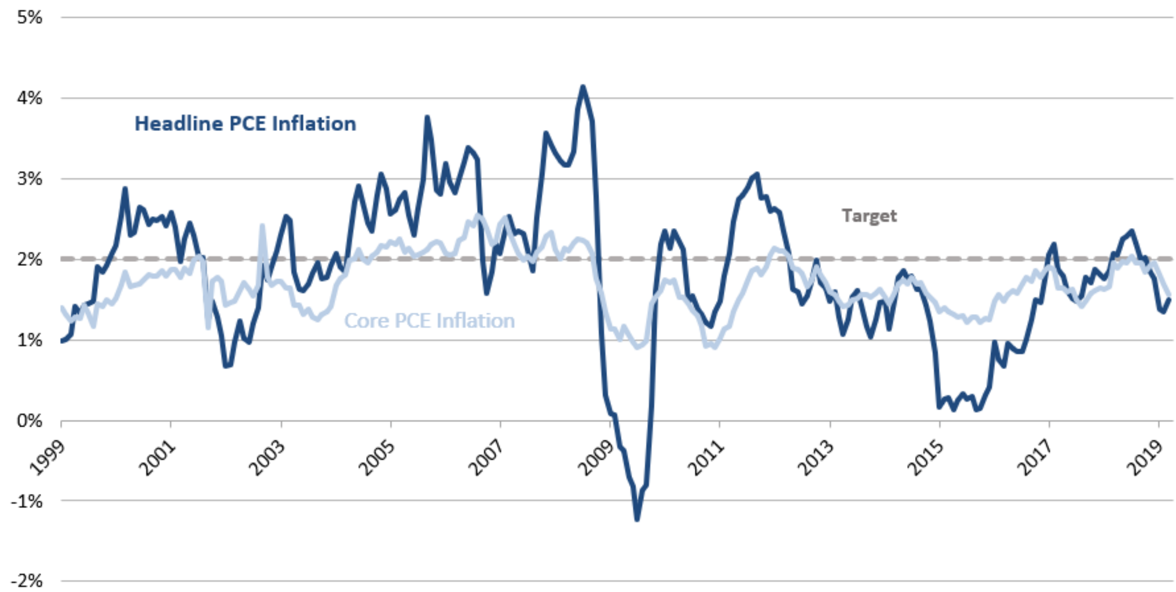


*Figure 5: Inflation targeting in the US over the last two decades.*

*Source: Haver Analytics & Wessel, 2019*

## 6.4 SEIGNIORAGE

The main revenue stream for the central bank is the seigniorage it earns. It is a function of notes outstanding. If there were a shift away from notes, it could hamper the central bank's revenue stream. According to Engert and Fung (2017), the central bank might have to rely on government funding, which would undermine its autonomy. This situation is not the case in most countries except for Sweden and Norway. Possible solutions to this problem would be to charge higher fees for the services it provides or imposing non-interest-bearing reserve requirements on bank deposits. Engert and Fung (2017) do not believe it would be necessary to implement a CBDC, as there is no real threat to seigniorage.

Seigniorage is equal to the face value of the instruments multiplied by the prevailing interest rate, less production, and other costs. Emphasized by Engert and Fung (2017), the changes in seigniorage then depend on the demand for a CBDC and whether this would cost less to produce than cash. Therefore, the demand for CBDC needs a closer examination to assess the impact on seigniorage.

### *6.4.1 Demand for CBDC*

A CBDC would be less costly than banknotes and could be a more secure way of purchasing for consumers. Without transaction fees from the central bank, it would be more profitable for merchants to use it instead of cash. The reason for this is the low processing costs associated with a CBDC in comparison to cash or current digital solutions. They also point out that a CBDC is subject to the risk of theft and loss, which would discourage its demand. However, cash is also subject to this risk, and therefore it does not reduce the attractiveness of a CBDC. Engert and Fung (2017) consider a CBDC without interest, but if it were to be interest-bearing, it is reasonable to expect higher adaptation.  This design would, on the other hand, lower seigniorage as the central bank would be required to pay out interest on the CBDC. The total seigniorage will increase if the profit from the higher demand outweighs the costs from paying interest. Therefore, there seems to be a reasonable basis to justify that the demand for CBDC would be present, and Engert and Fung (2017) believes this could increase seigniorage.

## 6.5 PRIVATE CRYPTOCURRENCIES

When first introduced, cryptocurrencies were considered small and insignificant compared to the global behemoths such as the dollar or the euro. As blockchain became more recognized, these cryptocurrencies have surged in value. At its peak in January of 2018, the total market capitalization for cryptocurrencies exceeded 700 billion USD. Bitcoin was the largest by far, with a market cap of 250 billion USD (Trading Views, 2019). This change in market capitalization was enough to catch the attention of the public and not least, the central banks. Regulating the economy through monetary policy has been an essential function to keep financial stability. As these new currencies make their way into consumers' pockets, possibly weakening the authority of the central banks, it could crucially affect their ability to regulate the economy.

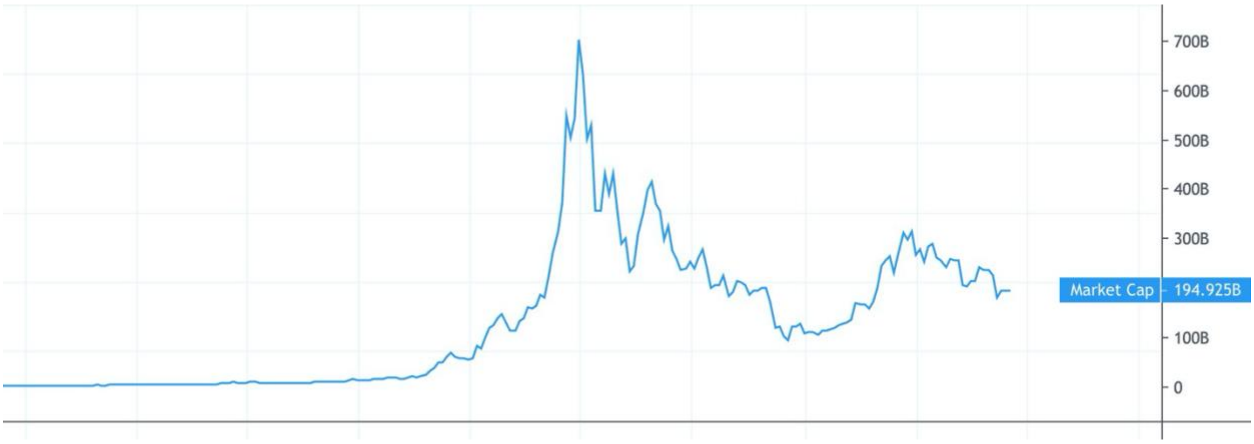


*Figure 6: Total market capitalization of cryptocurrencies from 2016-2019.*

*Source: Trading Views, 2019*

While the first iteration of cryptocurrencies has proved to be a major contender, especially in the long term, then currencies released by private companies might be an even more significant threat. Facebook has, as of the second quarter of 2019, 2.41 billion active users worldwide (Clement, 2019). With their Libra initiative, they aim at providing a new currency that would seamlessly integrate into their platform and serve as a payment option for their users, whether it be for domestic or international transactions. The Libra foundation consists of multiple companies with large user bases, which also could introduce Libra as a currency. The barrier to enter the traditional cryptocurrencies market is high, as they generally require a wallet to hold funds and then need to keep the private key secure. Facebook, on the other hand, already has a large pool of expertise on making products user-friendly, and the barriers for entry would most likely be lower and lay the foundation for mass adoption of their new currency.

If Libra is introduced and embraced by a majority of its user base, the central banks could face a significant challenge. A large part of transactions would occur on the Libra platform, eventually leading to more of the consumer's funds stored in this currency. The Norwegian central bank mentions that monetary policy would not affect private cryptocurrencies like Libra, and therefore the central bank could find it challenging to regulate the economy appropriately (Norges Bank, 2018a). A CBDC could be more competitive against these new cryptocurrencies, especially those like Libra, than current fiat currencies. As physical cash provides no interest rate, it would not offer good competition against Libra. An interest-bearing CBCD, on the other hand, would provide competition to these new private currencies.

# 7. EFFECTS ON COMMERCIAL BANKS

The public never actually interacts with the central bank directly. Commercial banks serve as an intermediary between the people and the central bank. Some of their services include taking deposits, granting loans, offer financial advisory, and creating money. Commercial banks are an essential part of any developed society. Through banking, large financial sectors have blossomed, real estate purchasing has become a possibility for large parts of the population, and it has been an integral segment of the global economy. In Norway, the aggregate assets of the banking sector alone is a staggering 180 percent of the Norwegian GDP (Finance Norway, 2019). Recent crises such as the one in 2008 have shown the dangers connected to such a significant sector consisting of mostly private banks and the power they wield in society. In the event of a bank run, cases from the US and UK have proven that even large organizations cannot always handle the enormous pressure from a shock such as the one experienced in 2008. If a CBDC offers more attractive properties than cash, it could most likely affect the commercial banking industry.

## 7.1 FUNDING

In the European Union, commercial banks obtain, on average, around 30 percent of their funding through customer deposits (European Banking Federation, 2018). A similar figure exists in Norway, where customer deposits account for over a third of a bank’s funding (Norges Bank, 2018b). The interest rate on such deposits varies but is generally considered to be relatively low compared to other investment options. A CBDC could introduce the possibility of customers owning a deposit account in the central bank, through an authorized intermediary, or hold CBDC through a register-based solution. This possibility would then be a risk-free investment. As claims on the central bank are safer than those on commercial banks, a CBDC might cause a shift away from traditional bank deposits. This change would largely depend on whether the CBDC is interest-bearing or not.

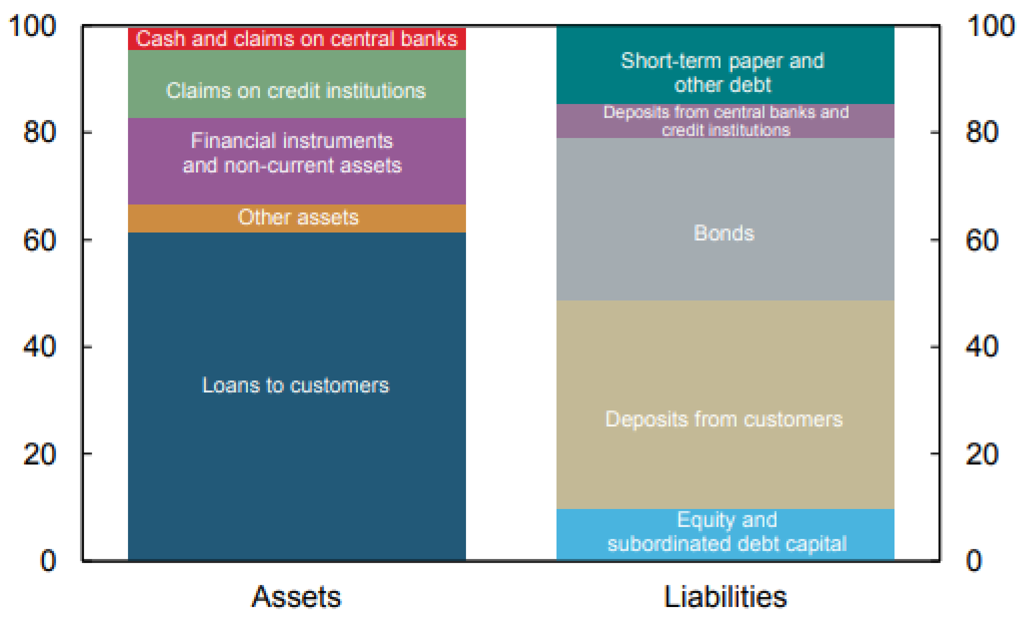


*Figure 7: Assets and liabilities for Norwegian-owned banks*

*Source: Norges Bank, 2018b*

### *7.1.1 Non-interest-bearing CBDC*

In the scenario of a retail CBDC without interest, the commercial bank deposits would most likely not be significantly affected. As long as they offer an interest rate higher than zero percent, consumers would keep their funds in bank deposits. Engert and Fung (2017) believe there would be some displacement of bank deposits, but due to not earning any interest on CBDC, there would be no real incentive, except for safety.

A CBDC will serve as an option if there are uncertainties regarding the solvency of the commercial banks. Engert and Fung (2017) believe stress-periods could prompt a shift from bank deposits into a CBDC. This shift could be the case in an adverse shock where the consumers would rush their money out of the commercial banks and into CBDC. Since a blockchain can accomplish this quickly, it could happen in a matter of seconds or minutes.

### *7.1.2 Interest-bearing CBDC*

If the central bank issued a CBDC with deposit accounts at the central bank, which pays interest, then consumers would be incentivized to move their funds there. That is unless the commercial bank can offer a higher interest rate on their deposits. This interest-bearing CBDC would serve a similar role to short-term government bonds as it would be the risk-free rate in the economy, but it would have far lower friction when transferring funds. Therefore, an interest-bearing CBDC would set a floor for the rate on short-term government bonds.

The Danish central bank believes a CBDC would be a safer claim than commercial bank deposits (Danmarks Nationalbank, 2017). Households might be inclined to shift a large part of their holdings from bank deposits to CBDC, impacting the banks' funding opportunities. However, Chiu, Davoodalhosseini, Jiang, and Zhu (2019) pointed out that the interest rate on the CBDC would mainly determine this possible shift. A low or intermediate interest rate could improve lending by seven percent and a total output of GDP by one percent, as long as the interest rate is not too high. The CBDC interest rate would need to be kept in the intermediate range. Engert and Fung (2017) also found that banks would be able to compete effectively with a CBDC as long as the interest rates were not too high, but there might be a modest contraction of intermediation, increased volatility, and less funding for the commercial banks. Meaning, Dyson, Barker, and Clayton (2018) also share this view and believe there is a risk for disintermediation, but commercial banks should be able to contend with this increased competition. There is no real consensus on the effects on bank funding, but generally, a high-interest rate could result in a decrease in bank funding. However, as pointed out by multiple papers, banks could effectively compete if the interest rate on CBDCs was in the low to intermediate range.

## 7.2 POSSIBLE CHANGES FOR THE COMMERCIAL BANK

To view the effects a CBDC could have on commercial banks, a consideration of the possible changes banks would have to make in order to compete with this new form of currency is needed. This section assumes an interest-bearing CBDC as this would have the highest impact on banks.

### *7.2.1 Raise deposit rates*

An obvious solution to a CBDC would be to raise deposit rates to incentivize consumers to put their money into the commercial bank, which is highlighted by Engert and Fung (2017) and Meaning et al. (2018). To accommodate this increased cost, banks might raise the risk of their investment in the hopes of higher returns. If the banks were to go down this route, there would undoubtedly be a need for regulatory oversight to ensure the health of the financial system. There are several other alternatives for funding increased deposit rates.

*Higher lending rates*

One option is increasing the cost of loans. Whether it is through increased lending rates or other fees, it could be a natural reaction as deposit accounts would become more costly for banks. Engert and Fung (2017) believe that increasing lending rates would be a likely response. This increase might especially affect consumers in the lower wealth brackets as they have fewer options when applying for loans. There might be innovations within the Fintech sector, such as peer-to-peer lending, which could alleviate some of these problems, but there would most likely be a reduction in lending activity for this group. Reacting with higher lending rates could, as a result, lead to less financial inclusion.

*Change in bank lending*

Keister and Sanches (2019) believe a CBDC would reduce bank lending in a perfect competitive banking sector, while Chiu et al. (2019) find an increase in lending of seven percent and a positive impact on deposits under an imperfect competitive banking sector. Andolfatto (2018) argues there is no impact on bank lending, but it may have a positive effect on bank deposits by offering higher interest rates. As the existing research in this area is conflicting, the exact effects a CBDC would have on bank lending are unclear.

*Cost reductions*

Another option for banks would be to reduce their costs. With automation and fintech innovation, we have seen a switch to more online banking and new solutions that reduce the need for manual labor and increase efficiency. A CBDC could provide a more efficient form of money and reduce the costs of banks associated with handling physical cash. As there is no available data on the effects of such a system, it is hard to predict the effect this would have, but in theory, it could offset some of the costs for a commercial bank. Engert and Fung (2017) believe banks would undertake such cost-reductions to remain competitive.

*Higher risk*

A possible reaction could be increased risk-taking from commercial banks in an attempt to provide a higher deposit rate. As Chiu et al. (2019) explain, this could increase the total risk associated with the financial system and, in turn, make it less stable. Engert and Fung (2017) also highlight this as a possible reaction. If commercial banks increase their risks to obtain higher returns, the central bank might need to provide stricter rules and guidelines, as well as actively regulate the sector. However, the other options considered above could prove to be effective in deterring commercial banks from seeking higher risks.

### 7.2.2 Bundling services

As mentioned, commercial banks are not only in the business of taking deposits but also grant loans, contribute with financial advice, do risk management, and assessment. Often these services are offered separately and at an additional cost. Engert and Fung (2017) predict that banks are likely to bundle such services together to incentivize customers to keep their funds in deposit accounts. Since a CBDC would not offer competing services, this could be an area where commercial banks could focus their attention in an attempt to create more value for their customers.

## 7.3 BANK RUNS

In cases of adverse shocks, there is often a flow of cash away from commercial banks as the general public fear for the solvency of banks. The liquidity of the banks becomes constrained and could, in the worst-case scenario, lead to bankruptcy. Before the age of digital banking, there would be long lines outside the banks, where people attempted to withdraw their funds. In the digital era, this has become easier, and with the touch of a button, moving funds has become instantaneous. Implementing a CBDC could reduce friction, and with a risk-free substitution readily available, even small shocks could cause dramatic situations with the public moving all their assets to a CBDC. Whether it is interest-bearing or not would most likely not have an impact as consumers are less interested in returns in the event of a crisis. This property of a CBDC would undoubtedly pose a significant risk to the financial system, and the central bank would need to make sure specific tools are in place to mitigate such risks.

The Norwegian central bank (2018), Engert and Fung (2017), and Meaning et al. (2018) all believe there is an increased risk of a digital bank run by introducing a CBDC. It would be easier to move funds from a bank deposit into a CBDC, and this could prove to be a considerable risk for the banking sector. The Danish central bank believes restricting the amount of CBDC a household can have would reduce this risk, a view shared by Meaning et al. (2018). In order to assess the risk associated with CBDC, one must consider other mitigation options for bank runs.

### 7.3.1 Lender of last resort

A strategy proven to be effective against rumors of bank solvency is the central bank's position as the lender of last resort. If a bank were to go bankrupt, the central bank would ensure the bank's solvency. After the financial crisis of 2008, this policy has almost single-handedly stopped bank runs. Therefore, to ensure the central bank retains this ability, there needs to be a contingency in the creation of CBDC that would allow the central bank to increase its supply in the case of an emergency. This feature is in stark contrast with current cryptocurrencies such as Bitcoin that have a specified total supply, or Ethereum who do not have a total supply limit, but there is no way to "mint" large amounts of coins in a short timeframe.

One option is to store a large amount of CBDC in the central bank in the case of an emergency. However, this is inefficient, which means it is highly unlikely that such a strategy will be employed. Another option could be to use smart contracts or manually allowing the creation of large amounts of CBDC if the circumstances warrant it. If one opts for a smart contract, there might be less uncertainty involved, as the central bank is unable to affect when one enacts this strategy. The reason for this is because it will only occur when a situation meets specific criteria. For example, if a bank has engaged in excessive risk-taking, it might not be eligible for an emergency loan from the central bank. Pfister (2017) argues that such a pre-announced lender of last resort policy must exist in order to limit moral hazard. From the view of the central bank, it would be preferable to have full control over such a tool, but from a consumer standpoint, a smart contract could be more favorable. No matter the strategy, proper regulatory oversight is needed to avoid excessive risk-taking by banks.

### 7.3.2 Deposit insurance

This tool is similar to lenders of last resort. However, deposit insurance targets the depositors instead of the banks. If the bank goes bankrupt, the deposit is still paid by the central bank up to a specified limit. If there is a central bank guarantee for deposits in commercial banks, there is still the problem in terms of how the central bank would finance such an operation. Therefore, they need to have a clause in the creation of CBDC to increase the money supply if needed.

Kumhof and Noone (2018) argue that the efficiency of transferring CBDC could make it less likely for a bank resolution, and in a world without CBDC the risk for a bank run is just as likely. As long as the CBDC is constructed to be able to handle drastic increases in quantity, a bank run for the entire financial sector is highly unlikely. Therefore, the introduction of a CBDC does not necessarily increase the risk of bank runs.

## 7.4 PRIVATE INNOVATIONS

FinTech innovation has increased in recent years, offering competition to the established commercial banks, as shown in figure 8. A CBDC built on blockchain technology could open up for a range of new companies creating applications on top of this money. With a centralized system, it would require more cooperation between the central bank and commercial banks, but a decentralized system enables the possibility for innovation through fintech services. If a company introduced a new way to conduct peer-to-peer lending using this new system, banks might suffer from lower lending activity. However, if this led to more financial inclusion, especially in emerging economies, then there might be hidden synergies that are hard to quantify (Adrian, 2019). One example could be a micro-lending service using a peer-to-peer principle that would allow entrepreneurs or other startups to receive loans. The possibility of this would enable their business to grow, which at a later stage could attract banks. Therefore, this would then give opportunities to people who would otherwise have been overlooked by the current banking system (Adrian, 2019). Innovations in transaction mechanisms could serve not only to be beneficial for the public but also to the banks, resulting in lower costs.

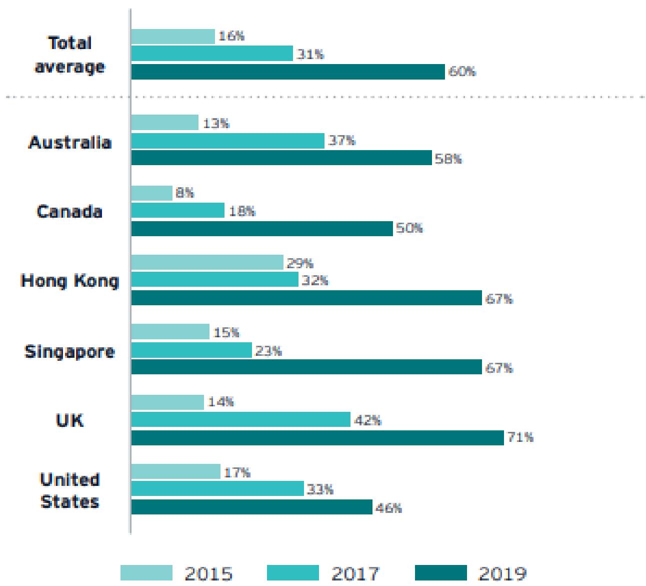


*Figure 8: Comparison of FinTech adoption in six markets from 2015-2019*

*Source: Ernst & Young, 2019*

However, there could be new services that compete directly with established banks and could reduce their profits. An example could be new online banks built on the technology of CBDC directly competing with the current banking sector. These online banks could provide services at lower costs than their counterparts. This possibility would be dependent on how much of this new system companies could access and the regulations surrounding such innovations.

## 7.5 OTHER EFFECTS ON COMMERCIAL BANKS

Up to this point, the mentioned effects have mostly been regarding possible problems the introduction of a CBDC could have on the current business model for most commercial banks. However, with new technology, these banks could also experience some benefits.

### *7.5.1 Financial inclusion*

In advanced economies, almost everyone has access to banks and the services they offer. The situation in emerging economies is entirely different. In 2017, an estimated 1.7 billion people around the world lacked proper access to financial services (Demirguc-Kunt et al., 2017). Figure 9 shows the report on financial inclusion by The Global Findex database. They found the cost of bank accounts and the distance to financial institutions to be leading causes for financial exclusion. A CBDC built on a blockchain requires far less technological infrastructure to operate, and the citizens only need a mobile phone and internet connection, which is far more common than financial services. The potential source of new customers is immense in such areas of the world, and a CBDC could lead to an expansion of banks to accommodate this growth. Andolfatto (2018) found this when assessing the impact of a CBDC on private banks. The paper highlights that areas with fewer banks that have a monopoly could benefit the most from this. Therefore, this could also be a possibility for the existing banks. If banks in advanced economies are forced to downsize, there might be room for expansion into these emerging markets as they already have the expertise needed, and the necessity for banking services could be substantial.

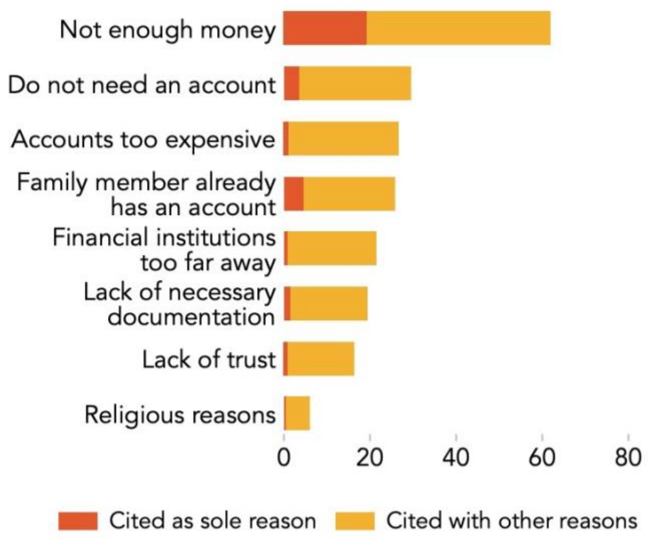


*Figure 9: The main hurdles for obtaining a bank account*

*Source: Demirgüç-Kunt et al., 2018*

### *7.5.2 Stronger and more resilient banks*

Assume that banks in advanced economies would experience a modest contraction due to the introduction of a CBDC. While in the short-term, this would have a negative effect, the long-term effects could prove to make banks more efficient, less bloated, and more resilient to adverse shocks (CPMI, 2018). As discussed in the previous paragraph, this could potentially open up the possibility of using surplus experience in emerging markets and facilitate greater financial inclusion. A CBDC could also force current commercial banks to innovate and create new services to compete with both a CBDC and new companies within this space.

### *7.5.3 Mintettes*

Danezis and Meiklejohn (2015) point out a possible new area for the banks as mintettes in a proof-of-authority type of protocol. Commercial banks could be the ones validating the transactions as they occur and merging this into the full blockchain at the central bank. It could be possible to adopt a similar system to Ethereum where the miners, or in this case, the commercial banks, would be rewarded with a transaction fee. This fee could be another stream of income and could be useful in offsetting some of the possible losses in funding from deposits. Danezis and Meiklejohn also show how this system can be extremely beneficial, conducting settlements and verification in a fraction of the time that current cryptocurrencies use. Such a solution is advantageous for commercial banks, as well as the whole banking system as it circumvents the argument of slow blockchains. Figure 10 shows this method.

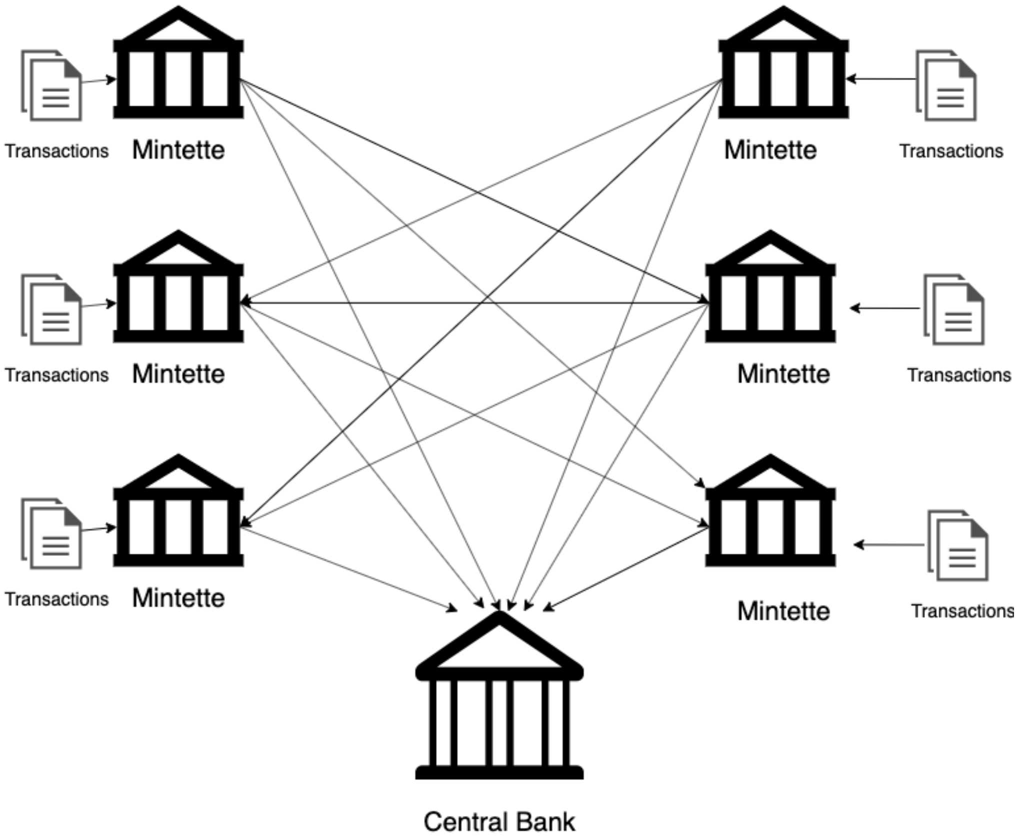


*Figure 10: Commercial banks could serve as mintettes for the central bank*

*Based on: Danezis & Meiklejohn, 2015, pg.4*

# 8. EFFECTS ON PAYMENT SYSTEM

## 8.1 PAYMENT

In the modern economy, paying for goods and services or sending money between peers is often taken for granted. The systems underlying these transactions are always in development, and modern technology has increased the number of transactions conducted every day, lowering settlement time. Transaction conducted with Visa can take up to two days, while other options such as American Express range from two to five days (PayPal, n.d). In Norway, Vipps cooperates with banks to carry out settlements between bank accounts in just a few seconds. However, card payments through Vipps can take up to three business days. (Vipps, n.da) For merchants using Vipps, this process can be up to five days (Vipps, n.db). Transactions across borders have generally been slow, but as global commerce is rapidly growing, a need for faster transactions drive innovation forward. New systems such as SWIFT have shown to be able to lower settlement time for cross-border transactions to 25 seconds (GPI, 2019). Visa has launched a blockchain to compete with SWIFT in this $125 trillion market, using DLT to lower settlement time (Minnock, 2019). A CBDC could be another option in the search for more efficient systems.

### *8.1.1 Immediate settlement*

The settlement time for popular blockchains like Bitcoin and Ethereum ranges from 10 minutes to 14-15 seconds, but smaller-scale blockchains have proven to be even quicker. Even though these blockchains use a proof-of-work consensus model, considered a slower consensus mechanism, there has been a reduction in settlement time. If one were to base a blockchain on a permissioned structure and use a delegated Byzantine fault tolerance consensus mechanism with the commercial banks as the nodes, one could achieve both high transaction speeds and low settlement times. NEO has been able to process 1000 transactions per second and estimate that by 2020, it will achieve 200 000 transactions per second (Mushtaq, 2018). Another possibility is a double consensus protocol like Futurepia has employed. It has shown the ability to process 300 000 transactions per second (Wisestone, 2018). This increase is a huge leap forward from the 1700 Visa currently handles.

While a transaction speed of 300 000 per second might seem unnecessary, this could open the opportunity for micropayments. Traditionally, the payment for goods or services has been in lump sums. For example, one pays a taxi fee once one arrives at a destination, or workers are generally paid once a month. With high transaction and settlement speeds, payments could occur every second, every hour, or every day. This possibility opens up the prospect of new applications not thought conceivable before. Possibly, in the future, the process of paying workers their salaries happens every day, or even every hour or minute, it happens instantly.

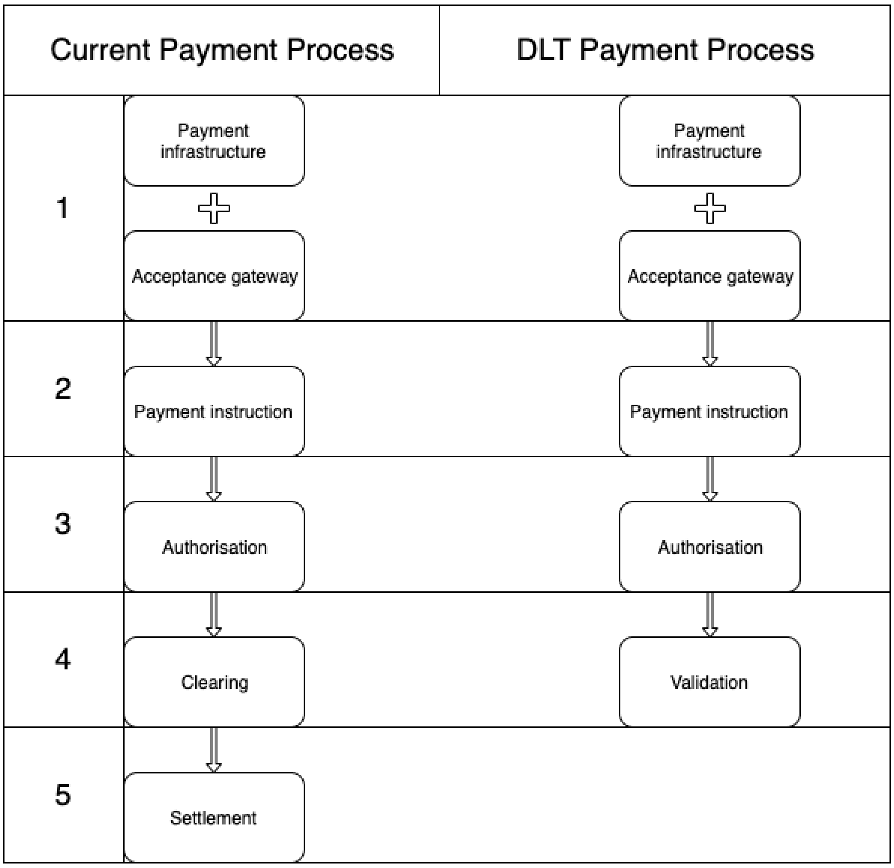


*Figure 11: The difference in payment processing*

*Based on Wadsworth, 2018a, p.5*

### *8.1.2 Peer-to-peer payments*

In the advanced economies, new technological advancements on the frontier of peer-to-peer payments have increased over the last few years. As mentioned, Vipps has revolutionized the process of transferring money digitally between peers, and the solution has been incredibly popular. With the introduction of the Revised Payment Service Directive (PSD2), payment services previously only available for commercial banks, are now accessible for everyone.

This new legislation paves the way for innovation in the FinTech sector that will likely increase the competition in the payment market. New competitors in the peer-to-peer market are therefore not unlikely. While based on the current system, a CBDC could offer another alternative, as Fung and Halaburda (2016) explore. One of the main benefits of Bitcoin is the ease of transferring funds between peers, and this could also be the case for a system using a CBDC. Instead of reconciling the ledger at each bank, a distributed ledger offers a more efficient system where one ledger records every transaction, negating the need for reconciliation between banks. Figure 11 shows the difference in peer-to-peer payments.

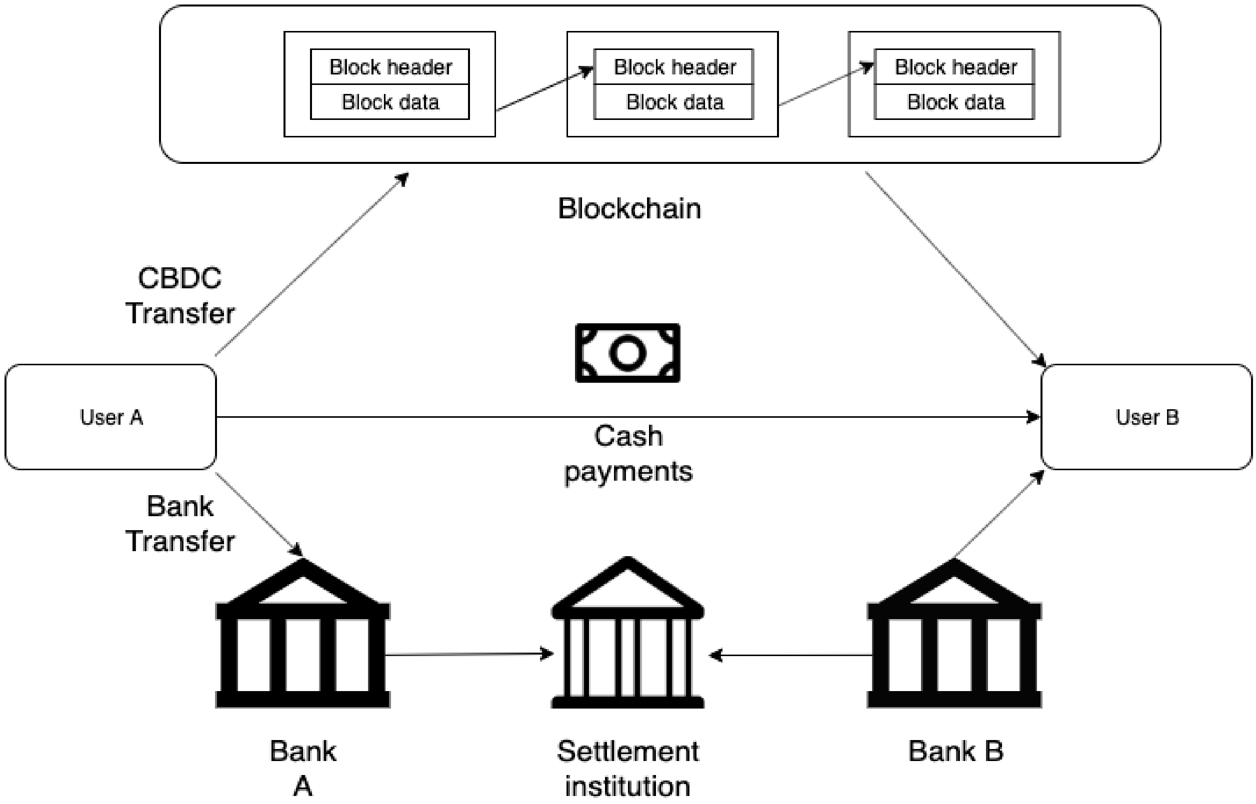


*Figure 12: Difference in peer-to-peer payments*

*Based on Okex, 2019.*

### *8.1.3 Cross-border payments*

As previously discussed, the process for international settlement is not efficient, and costs are high. Chapman and Wilkins (2019) argue that while using blockchain technology might not be needed within Canada, due to how efficient the technology they have already is, it might be more useful for cross-border transactions. This feature is one of the reasons the Bank of Canada, among others, is examining the use of DLT in this process (Chapman & Wilkins, 2019). Cryptocurrencies such as Bitcoin have proven to work across borders despite the differences between countries. The reason for this is mainly due to Bitcoin having one ledger across all borders, and a similar system could work for a CBDC. Singapore and Canada have connected their experimental domestic payment networks based on DLT to make cross-border payments cheaper, faster, and safer (Helms, 2019). This possibility could lead to a more globalized economy with more efficient payment methods and financial inclusion. While trials of the SWIFT system have proven centralized technology could work, DLT, such as a blockchain, could prove to be equally as good, if not better.

### *8.1.4 Costs*

A payment system using a CBDC could decrease cost as it makes processing transactions faster unless a proof-of-work consensus is applied. Many companies have large sums tied up due to slow settlement times, an area that could improve through the implementation of a CBDC. By increasing the speed of these transactions, companies could see a reduction in costs related to such payments. Cross-border payments are also associated with high fees, and as discussed in the section above, a CBDC payment system could provide more efficiency and in turn, lower costs.

Fung and Halaburda (2016) discuss whether a CBDC could be cost-reducing, but point out that there are strong network effects in the payment markets that could hinder a new solution. This argument is a valid one, but if a CBDC could make the system faster, more efficient, and more secure, there should be an adequate incentive for the market to employ it. Furthermore, they highlight two possible areas for more effective systems, either through alleviating frictions or through less expensive methods of conducting transactions. Engert and Fung (2017) highlight the fact that low-cost electronic peer-to-peer payment methods already exist, and as such, a CBDC might not be able to lower costs significantly. Benos, Garatt, and Gurrola-Perez (2017) found DLT to potentially improve securities settlement, with higher efficiency and lower costs, but believe that the technology is currently not mature enough. Barrdear and Kumhof (2016) believe a system that is not fully centralized or decentralized, like a distributed permissioned architecture, could improve efficiency and resiliency, ultimately reducing costs.

### 8.1.5 Remittance

In the global economy, there is a substantial wage discrepancy between advanced economies and emerging ones. As a result, workers from the poorer countries relocate to a wealthier country in the search for higher wages. Often a large chunk of their wages is sent back to their family in their country of origin. This process is called remittance, which is a type of peer-to-peer payment across borders. Remittance is one of the largest sources of inflow of capital to emerging economies, as shown in figure 12. A flat fee and a percentage fee on the transaction are standard. There are quite high fees compared to what the advanced economies experience, often ranging from five to seven percent (Cecchetti & Schoenholtz, 2018). Fung and Halaburda (2016) mention that on top of the high fees associated with the remittance, there are also security concerns with these payments. Mailing or sending money is unsafe, and so most have to accept these high fees. It is generally cheaper to send higher amounts, which is why workers save their money and send it in bulk payments. As discussed above, cross-border payments could be made cheaper, and new peer-to-peer payment systems are possible with a CBDC. These payments could be an area where a CBDC proves to be most helpful.

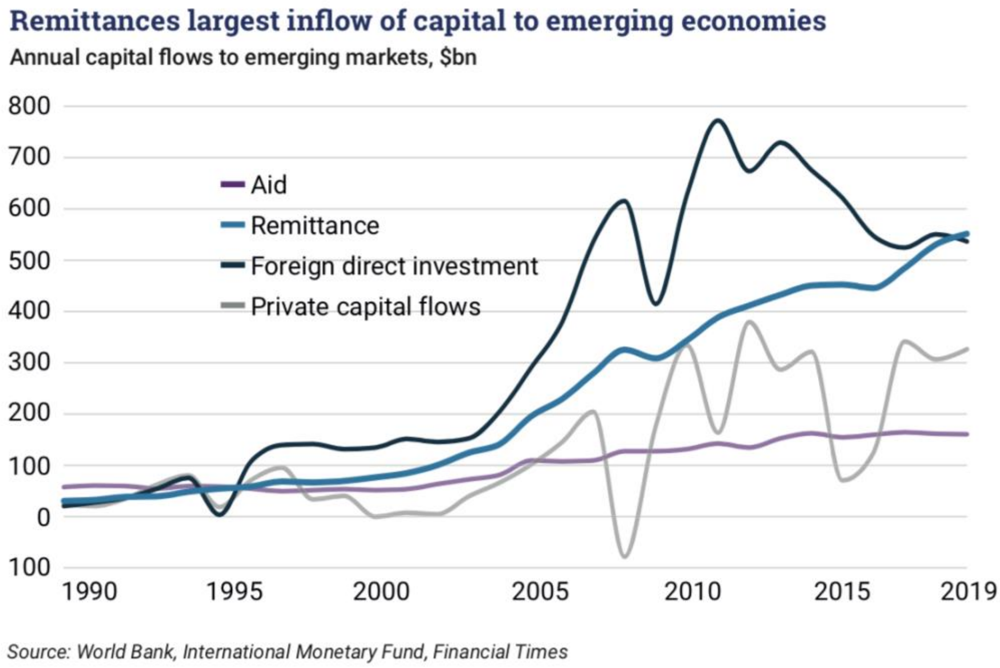


*Figure 13: Largest inflows of capital to emerging economies*

*Source: OMFIF & IBM, 2019, pg. 17*

### *8.1.6 Foregone transactions*

Fung and Halaburda (2016) discuss that a potential benefit of introducing a CBDC is opening up the possibility of conducting transactions that would typically not occur due to friction. Security, monetary, and non-monetary transaction costs are examples of possible frictions hindering transactions that would be economically beneficial. Fung and Halaburda (2016) list many frictions regarding online, point-of-sale, peer-to-peer, and remittance transactions, which will be considered briefly in order to give an overview of the frictions and how they relate in regards to a CBDC.

The first is in terms of online transactions, security, and privacy concerns, as users worry about the handling of their payment information. Current market solutions such as PayPal solve this by not allowing merchants to have access to credit card information. Blockchains such as Bitcoin solve this through the use of public and private keys and cryptography. The only stored information is the address of each account. A similar system is possible where a person could pay using CBDC without the use of a credit card, and only their address will be stored on the blockchain.

Online transactions usually have some fees associated with them, especially for small-value transactions. Some merchants might have low-price items that would typically sell, but due to the transaction fees, it is not feasible. As highlighted above, faster transactions and the introduction of micropayments could be a way to solve this problem and include these foregone transactions in the economy. At point-of-sale, there are usually security concerns, especially at smaller unknown merchants or street vendors, due to concerns of having one's credit card information stolen. In China, the use of QR-codes has solved this to a certain degree, as the vendor never has access to the credit card. A CBDC could employ a similar system, and through the use of public and private keys, one's credit card information is safe.

Peer-to-peer transactions have both non-monetary costs in the form of having to find an ATM to withdraw cash as well as fees for using electronic versions. New apps such as Vipps in Norway have reduced the non-monetary cost as sending and receiving funds can be done through a mobile phone. Fung and Halaburda (2016) also mention that some demographics, particularly older generations, might not adopt new technologies, and therefore their transactions are foregone. A CBDC will have little impact on this non-monetary friction if there is a system like Vipps in Norway that is already in place. For countries without such solutions, a CBDC payment system might similarly solve this problem as Vipps has done in Norway. Lowering the fees associated with these transactions is also possible. In sum, a CBDC and the payment systems associated with such technology could reduce the number of foregone transactions and establish a more efficient economy.

### *8.1.7 Large value payments*

For large-value payments, one uses RTGS systems. Engert and Fung (2017) consider the possible impact a CBDC could have when an RTGS system already exists. The CBDC would provide a general, open-access RTGS where all settlements, not just wholesale ones, can be done for large-value payments in real-time. The current system has advanced mechanisms to ensure both speed and security through a permissioned system with a trusted central bank at its core. When comparing a CBDC to the current RTGS, the report found that the RTGS system was more attractive compared to a CBDC for such large-value payments.

## 8.2 SECURITY

The banking system processes large amounts of money every day, and because of this, it is a primary target for malicious parties. An implementation of a CBDC would need safeguards against such groups, which is where blockchain could offer a useful solution.

### *8.2.1 Resilience*

Barrdear and Kumhof (2016) found that decentralized architectures improve the resiliency relative to the current system. Blockchain is incredibly difficult to hack or alter. In the entire history of Bitcoin, there has not been one successful hacking attempt. The built-in cryptography and consensus mechanisms make it close to impossible to hack. The only possibility is to conduct what is known as a "51% attack", where the attacker controls 51 percent of the computing power of the network. A central bank would most likely not use proof-of-work as Bitcoin does, but instead use another consensus model like proof-of-authority or proof-of-stake. If the central bank were to structure the CBDC blockchain using commercial banks as mintettes, then a hack would need to take control over the majority of these to be successful. The likelihood of this is low. Therefore, a CBDC that runs on a blockchain would be more resilient to attacks than its centralized counterpart.

Another essential aspect of blockchains is the removal of a central point of failure. If problems related to servers in the current system reach a critical point, the entire system could come to a stop, and transactions would not be processed. Distributed technology solves this. If one of the nodes in the distributed network experiences problems, the other takes over. There is no way to perform a DDOS attack or similar to stop the network as long as there are enough nodes. In a system where every commercial bank within a country functioned as one of the nodes, an attack on one of the banks would not affect the blockchain the CBDC runs on as the other banks would still function as normal. The distributed network of nodes makes it safer.

### *8.2.2 Privacy*

The digital age has increased awareness on the subject of privacy. Private companies are gathering considerable amounts of data, and surveillance is one of the government's most essential tools for maintaining national security. Cryptocurrencies can, in a way, be seen as a response to this as it attempts to offer privacy when conducting payments. For a CBDC, this could be troublesome as the public, assuming rationality, would prefer more privacy while the governments would want less privacy. To what extent a CBDC could offer privacy would be individual for each country, but a CBDC with little to no privacy could prompt a move to other currencies or cryptocurrencies and would thus result in less adaptation by the public. However, those who prefer privacy in terms of their transactions would likely use anonymous cryptocurrencies instead of a CBDC.

A CBDC would most likely need to offer privacy in the sense that no one could view the details of transactions and deposits except the central and commercial banks. It would not have the same anonymity as cash has, but it would be closer to the experience of using current electronic payments systems. The governing authorities would most likely need the ability to track transactions in their efforts to stop crime and resolve conflicts. One solution is to require legal means in the form of a warrant to be able to do this. In this case, there would not be constant surveillance of people's transactions, only in situations where there is a suspicion of criminal activity. While some may stray away from using a CBDC due to this, this group of people would likely resort to using other private cryptocurrencies.

### 8.2.3 Permanent record

A blockchain provides a distributed, immutable ledger. Going back and rewriting earlier transactions is practically impossible. This feature makes blockchain secure from hacking and provides a permanent record of every transaction ever made on it. If there is any uncertainty on a transaction, all the details are available on the blockchain. When two parties disagree on the information about a transaction, the blockchain would contain the answer. It serves as an undeniable truth, containing all the information regarding past transactions. Chapman and Wilkins (2019) mention that recordkeeping in a ledger is a well-established service dating back thousands of years. However, the blockchain makes it incontrovertible and allows information sharing among all participants. Another important aspect is the efficiency this results in as redundancy with recordkeeping is reduced, and there is less need for multiple points of verification. Chapman and Wilkins (2019) believe this to be two of the reasons many organizations, specifically central banks, are interested in blockchain technology.

## 8.3 FINTECH

With the introduction of PSD2, new companies can enter into the payment and to a degree, the banking industry. These new companies are FinTech firms who use technology to offer financial services. In the last few years, this sector has been growing at an incredible rate, and introducing a CBDC could open up more possibilities. Smart contracts form the basis of the Ethereum platform, which are computer programs that execute a predetermined agreement. This aspect has resulted in new business opportunities and new types of services. Anyone can use the Ethereum ecosystem, and a CBDC designed similarly could make the FinTech sector a highly valuable industry, leading to more workplaces and increased competition.

### 8.3.1 Innovations

Predicting what these innovations could entail is hard. New payment systems could be created not only for peer-to-peer use but also for retail or wholesale systems tailored to the individual's needs. Some might be transparent, like a system for government spending, while a peer-to-peer payment system might be less transparent based on the needs of the users. Peer-to-peer lending is already serving some needs traditionally bank lending failed to cover, and a CBDC could enhance this even more. Crowdfunding could become more efficient and governed through smart contracts. Micropayments could open up the possibility of entirely new applications and business models that are inconceivable with current technology. However, all these opportunities are contingent on a CBDC providing private companies access to certain functions and information. Adrian (2019) highlights the possibility this entails for the FinTech sector and also the positive impacts this has on financial inclusion

### *8.3.2 Competition*

Opening up the blockchain to developers could prove to be beneficial to the health of the financial system through increased competition. Barrdear and Kumhof (2016) believe that there is a lower barrier to become a transaction verifier in a distributed system, as opposed to a bank in a tiered system. This change could lead to more competition in payment services. Having a CBDC would be the same as having a narrow bank that is online-only and reserve-backed, which would compete with account services. It might be natural to consider increased competition as negative for commercial banks, but it could also make operations more efficient, and in turn, create a more resilient banking sector. It could also increase competition through the creation of new and unconventional services, in the same fashion that peer-to-peer lending has done for consumer loans.

## 8.4 EMERGING ECONOMIES

A CBDC has its merits in advanced economies, but emerging economies might benefit even more from a CBDC. In a lot of the less developed areas in the world, access to bank and financial services is scarce. There are fewer physical commercial banks, often far away from the smaller towns, and digital banking is not as advanced as in the wealthier nations. With a fragile technological infrastructure in place, financial inclusion in developing countries is a significant problem. Approximately 1.7 billion people remain unbanked, but a CBDC could be an essential piece to solving this problem.

### *8.4.1 Technological leap*

Advanced economies have, for decades, developed technological infrastructure, with large server farms, radio towers, large transaction systems, and other central pieces for a technological ecosystem. Emerging economies often have a primitive technological infrastructure in place, which is incapable of handling the same volume of transactions as an advanced economy. It takes time to build secure and efficient systems, and a CBDC can provide a leap into the future. Instead of trying to scale the existing technology, a CBDC built using blockchain can be utilized to provide fast and secure payment systems with a user-friendly mobile interface. Adrian (2019) views FinTech as an essential factor in increasing financial inclusion, and a CBDC could facilitate a more efficient technological structure. All that would be needed to use this service is an internet connection and a smartphone. In the globalized economy, transactions could happen in one country while being processed in another. For example, Norwegian commercial banks could serve as verification nodes in an African country. This process could be in place until emerging economies obtain the necessary systems and infrastructure. In most countries, such a solution is not necessary, but it could be a possibility.

Vodafone has launched an electronic payment system called M-Pesa based on mobile technology. This electronic money has proven to be a viable solution and verifies the idea that a CBDC, when used through mobile phones, could be beneficial (Monks, 2017). The main advantage of this is to avoid the time-consuming process of upgrading a fragile technological structure and instead take a technological leap to a mobile payment system based on a CBDC.

# 9. THE CASE FOR NORWAY

## 9.1 THE NORWEGIAN LANDSCAPE

A notable trend in the digital era is the transition from cash to digital payments, and few countries in the world have come as far as Norway in this process. Cash could eventually become unsuitable as a medium of exchange, which could leave the country without any form of legal tender. The Norwegian kroner (NOK) is currently a backup alternative to the electronic systems and is the main currency in the case of technological malfunction. In a nearly cashless society, the risk of not having a backup solution to the current electronic system could prove substantial.

The Norwegian base rate, currently at 1.5 percent, has been at historically low levels ever since the price of crude oil dropped by 44 percent in 2014 (Trading Economics, 2019; Kilian, 2015). If the central bank finds it necessary to reduce the rate further, towards zero or negative territory, the ZLB is likely to cause considerable challenges. QE is the usual response when approaching the ZLB. The use of QE is controversial, and if possible, most central banks avoid utilizing this measure. Inflation targeting policy is used in Norway to achieve stability and is currently at two percent per year (Central banking newsdesk, 2018). The actual inflation fluctuates, as shown in figure 13.


*Figure 14: Norway inflation rate from 1995-2018*

*Source: YCharts, 2019*

Commercial banks in Norway have a central role in the economy as the primary lenders to the public, resulting in loans being the main assets banks hold. On the other hand, deposits and bonds are primary sources of liabilities (Norges Bank, 2017). The commercial banks also offer a variety of services that are commonly used by the public, such as payment solutions and offering investment options. Although the banking sector was 180 percent of GDP in 2018, bankruptcies have not been common compared to other countries. This trend could be due to the deposit insurance the Norwegian Central Bank introduced for saving banks in 1924 and for commercial banks in 1961. Deposit accounts up to two million NOK are insured by the Norwegian Banks' Guarantee Fund. Along with close regulation from the central bank, this has been effective at mitigating bank runs (Norges Bank, 2017).

Payment systems in Norway have changed over the past years, with peer-to-peer payment and point-of-sale options such as Vipps proliferating. In a report from 2017, the central bank highlighted the costs of using cash as an essential factor for this, along with a high smartphone penetration of approximately 87 percent (Tankovska, 2019). Withdrawals from ATM cost, on average, NOK 5.50, while credit card transactions cost NOK 0.10 (Norges Bank, 2018b). The implementation of new and more practical payment solutions has, along with lower costs, decreased cash usage, and Norway is on a path to become one of the first cashless societies in the world.

## 9.2 MOTIVATIONS

A CBDC could be an excellent approach to ensure legal tender availability and to function as a medium of exchange as cash use is diminishing. In addition to this, cash is a risk-free credit alternative to bank deposits, and a CBDC could provide an alternative to this if cash is phased out. It could also be a substitute for current risk-free investments such as short-term government bonds through an interest-bearing design.

Cash would be the only payment option available for use if the current electronic system malfunctions. A CBDC would also be electronic, but through blockchain, the system could provide a robust alternative to the current centralized system. Every participant in the network would need to be taken down to paralyze a decentralized system, which makes it more resilient to both failures and attacks.

While Norway's base rate is not at the ZLB, there might be situations in the future where this floor confines the central bank. Through the introduction of a CBDC and the reduction in cash, the central bank could have other options than conducting QE. Replacing inflation targeting with price-level targeting could also be a valid argument for issuing a CBDC, as the former is less consistent. Another argument with regards to monetary policy is a possible threat from cryptocurrencies. While the current use of cryptocurrencies is low, Libra and others might pose a more significant threat to the NOK in the future. A digital NOK might be a solution to mitigate some of this risk.

Blockchain offers potential efficiency gains, which could apply to the payment system. In Norway, the current process is already highly capable of conducting transactions within minutes. Although card payments are still relatively slow when measured in settlement time, the efficiency increase of a blockchain does not seem to be an essential factor in Norway. The concept of micropayments could be an exciting opportunity if a CBDC can achieve higher transaction speeds than the current system offers. However, as this is still mostly conceptual, it does not warrant the implementation of a CBDC.

## 9.3 POSSIBLE CONCERNS ON CBDC

In a report from 2018, the Norwegian Central Bank highlighted an essential reason for the existence of cash. Economies of scale and network effects characterize the current electronic payment services, which could make competition scarce. In an economy without cash, these payment providers could achieve market positions similar to a monopoly and in turn, raise transaction fees (Norges Bank, 2018b). However, PSD2 lowers the barrier to entry for becoming a payment provider in Norway. Therefore, it would make it unlikely for someone to raise rates significantly as smaller payment providers could exploit the gap.

The potential threats to commercial banks explored in chapter 7 is another essential concern when introducing a CBDC in Norway. There is substantial uncertainty considering how it would affect banks, both in the short and long term. As the banks are central to the Norwegian economy, a significant disruption in the sector might be imprudent. Also, a CBDC could make commercial banks more prone to bank runs. Another concern is the possible change a central bank would need to make to its mandate, as some of the proposed properties of a CBDC could change the operational character of the central bank. If the public were to deposit money directly into accounts at the central bank, it could become a direct competitor to the commercial banks and overstep its role. This concern is mainly dependent on the construction of the CBDC.

## 9.4 TAXONOMY

The way the Norwegian central bank implements its CBDC will have a profound influence on its perception and its potential implications. All solutions for a retail CBDC discussed in Chapter 4 will be considered and its ideal employment in the context of the Norwegian economy. Preferably, a CBDC will work as a complement to physical cash in the short to medium term. Due to the likelihood that cash will be phased out, a CBDC could become a viable substitute. A wholesale CBDC, in regards to Norway, will not be considered due to the minimal effect it will likely have on domestic efficiency and security. As discussed earlier, a wholesale CBDC would not provide any significant upgrade to the current RTGS systems. Therefore, it would likely only be of high cost for the Norwegian central bank, with minimal advantages.

### *9.4.1 Token-based physical device solution*

In Norway, with the current technology and infrastructure, this approach could quickly be established. It would offer the highest degree of anonymity of transactions and would be the most similar to physical cash. This aspect could prove fruitful in presenting it as a substitute to the NOK for the Norwegian public. However, this "similarity" might prove to be problematic, given that cash usage is low and falling. A report written by Arvidsson, Hedman, and Segendorf (2017), calculated that the use of cash in the Swedish economy would become irrelevant by March 2023. A parallel can be drawn between Norway and Sweden as they have had similar trends in recent years. A CBDC would also fail to retain some useful characteristics of physical money, such as the true anonymity associated with it and the basic tangibility of notes. These aspects could ostracize certain demographics of the Norwegian public. For the younger generations, given the existence of contactless cards and Vipps, it could be seen as a step backward in terms of payment systems. Similar to Sweden, the older generations in Norway rarely use the newer payment methods, and cash usage is still relatively high (Barontini & Holden, 2019). This consideration means that a CBDC stored on a physical device could be problematic and would likely be a stop-gap solution. On top of this, the administrative costs associated with this approach would be high for the Norwegian central bank. Therefore, implementing such a solution in Norway is not optimal.

### 9.4.2 Token-based register solution

Implementing a token-based register solution could be the most viable option for the Norwegian central bank. Though the anonymity associated with these types of transactions is lower than with physical cash, it could be set up in a way that it would have higher anonymity than debit and credit cards. In 2017, there were 441 card transactions per capita in Norway (European payments council, 2018). Given that the anonymity associated with card transactions is lower than it would be with a register-based solution, one can assume that the general public would adopt this type of CBDC without much objection. This approach would also be highly secure through the use of cryptographic keys and codes and could lead to a smoother implementation of blockchain technology. It also opens up for the possibility of innovation from third parties and could be implemented through the use of a mobile application (Norges Bank, 2019). Hindrances to the realization of this solution are the higher development costs and a more extended development period. However, it would function well as a complement to physical cash in short to medium term, while ultimately being able to take over in the long term. Smartphone penetration in Norway is expected to be approximately 93 percent by 2024, meaning that most Norwegians will have access to this solution (Tankovska, 2019). This approach is also more dissimilar from notes and coins than storage on a physical device and would therefore not receive the same level of disapproval . Crucially, it would seamlessly function through the use of blockchain technology, which would facilitate the use of smart contracts that can benefit the payment system. Finally, this solution can be interest-bearing, which could open up for a range of new monetary policies once physical cash is phased out. This approach should entail limits and caps on the amount of money that the Norwegian public can transfer between this solution and their bank accounts, to deter digital bank runs. However, if implemented correctly, this solution is ultimately the most likely to succeed in the Norwegian socio-economic model.

### 9.4.3 Account-based direct access solution

An account-based solution is primarily better suited for a country if speed and cost associated with transfers are of the primary concern. However, depending on its implementation, a direct access solution can turn out to be somewhat controversial. The main concern with this approach is the fact that the Norwegian central bank would become a competitor in the banking sector. This change would be contrary to their mandate of upholding the stability of the financial sector. It would also end up increasing the size of their balance sheet, which would mean that its exposure to the market would increase and could jeopardize the stability of the central bank. This approach works well to increase financial inclusion, as it gives the unbanked access to an account in the central bank. However, Norway is one of the countries with the highest access to banking services in the world (Norges Bank, 2017). Therefore, it could be unnecessary to implement this solution. Another problem with allowing the Norwegian public to open an account directly at the central bank is the fact that it would be a massive administrative undertaking. New departments would need to be established, such as customer relations and mobile banking, as well as integration with current payment systems. It is unlikely that the Norwegian central bank would have the resources available for such an undertaking.

A possibility for this type of approach is if the Norwegian central bank implements it through a closed account solution. This approach would then reduce the number of transactions that it would have to validate, it would not need to invest considerable amounts of resources into establishing links to the current payment systems, and the central bank would not overstep its role and become a competitor for commercial banks. Norges Bank (2019) points out that this solution could be easily combined with local storage on a physical device, meaning that it could be decentralized, allowing for offline use. However, conducting payments can only be done between people who have an account in the central bank, making it is a weaker substitute for bank money than an open account solution. It would be similar to the way private e-money, such as PayPal, now operates. No matter if implemented through an open or closed account solution, this approach would most likely be underutilized by the Norwegian public, except in periods of financial recession, viewing a CBDC account as a more secure store of value. Therefore, it is doubtful that this approach would be successful in Norway.

### *9.4.4 Account-based indirect access solution*

This type of CBDC, nicknamed synthetic CBDC, would most likely have a higher level of success in the Norwegian market as opposed to a direct access approach. Account-based approaches are focused on mimicking bank accounts and, if used for a transaction, could be conducted either through debit cards or Vipps. The chief advantage of this approach is that it limits the burden placed on the Norwegian central bank and allows it to continue its primary objective as the overseer of banks. However, this type of CBDC would not work as a supplement to cash, but would rather be a competitor for depositors accounts in commercial banks. Nonetheless, as only 11 percent of transactions are conducted in notes and coins, not being a direct supplement to cash should not be a problem in Norway (Flatraaker, 2018). As discussed in Chapter 7, it could also be a healthy form of competition.

Given that interest is paid on these DCAs, they would set the lower bound for what commercial banks could place on their deposits. This feature would then work similarly as the base rate that banks receive from the central bank, which then affects the lending rate that they offer their customers. By outsourcing the entire infrastructure process to private companies, it could build on the existing networks of Vipps that already has a large user base in the Norwegian market. If these DCAs were set up in well-established Norwegian commercial banks, they could function similar to BSU, young people saving accounts. The difference would be that the interest rate would be lower while increasing its security. A cap, similar to BSU accounts of 25 000 NOK a year, could also be applied.

Implementing DCA could function well in the Norwegian economy, though few may end up utilizing these types of accounts, making the cost of implementing them too high compared to the potential gains. It would assist in making physical currency redundant in the future, and given that this mechanism is more efficient than a token-based solution, a cost-benefit analysis would need to be conducted to compare the two. Therefore, one can conclude that this type of CBDC might work for the Norwegian market, depending on what the ultimate goal of the central bank is.

## 9.5 BLOCKCHAIN STRUCTURE

Most cryptocurrencies have adopted a permissionless and public structure. Blockchain offers decentralization, but in the case of a CBDC, this structure might be undesirable. A more centralized structure could be preferred as the central bank would want to continue as the primary authority, but this diminishes certain benefits of blockchain. Therefore, this section proposes two different structures. The first builds upon the work of Danezis and Meiklejohn (2015) and their RSCoin, and the other solution is similar to the current private cryptocurrencies.

A permissioned and private structure could be the most attractive option for the Norwegian central bank. This configuration is appealing because of the sensitivity of the information stored on the blockchain, and the central bank would maintain control over transactions. It is natural to think that a central bank would not allow anyone to be a block producer, as the rules are comprehensive and strict. Although the information on the blockchain is encrypted, allowing read access to anyone might be unwise due to the sensitive information contained on the ledger. Therefore, a structure akin to the RSCoin could be promising. This configuration entails less decentralization than some cryptocurrencies but is still less centralized than the current system.

In an RSCoin system, the commercial banks would be the block producers, which would not be far from their current role. The transition to a CBDC would not be as comprehensive. Banks receive transactions, followed by ensuring that rules are upheld and add the block to the blockchain. Commercial banks and the central bank would share this ledger. The Norwegian central bank could use the distributed ledger to oversee transactions and examine the economy. As the blockchain is relatively centralized, there is no need for a proof-of-work consensus model, and more efficient algorithms can be employed. Block speed would likely be high, and the system could utilize the potential speed increase of a blockchain to its full extent. In Norway, this structure could be a sound solution as the commercial banks are technologically proficient and could easily transition to the use of a blockchain. Such a structure would be an incremental improvement on the current system but does not fully utilize the advantages of blockchain.

Another possible solution is to decentralize the block producing function to a greater extent. In the Bitcoin protocol, anyone can become a block producer, and a similar system might prove to be possible. One restriction would be to require identification through, for example, BankID to gain permission to produce blocks. The block producers would earn either CBDC from the central bank, in a similar fashion to bitcoin producers earning Bitcoin, or through transaction fees, similar to Ethereum. This structure would enable anyone to become a block producer and participate in this process. The blockchain properties, such as resilience through decentralization and avoiding a central point of failure, would be fully utilized while mitigating some risk through identification.

The consensus algorithm in this proposed decentralized system could be a proof-of-stake or DPOS, combined with the identification property of a proof-of-authority model. It would serve as an efficient alternative to proof-of-work while mitigating risk through the concept of proof-of-authority. With regards to the read properties, securing the ledger through encryption could open it to the public, conveying a higher degree of transparency. If the Norwegian central bank wants to limit the read permissions, they could implement a restricted access protocol. By applying for access, those who need it for new business endeavors can receive access permission, after a thorough screening process. This structure utilizes more of the benefits of blockchain but could be a riskier option. As Bitcoin has shown, through a good consensus algorithm and strong cryptography, one can mitigate this danger, and therefore this proposed structure should not imply a significant risk to the system. The Norwegian central bank would still be the only issuer of CBDC, but the transaction system is open to the public.

## 9.6 CONSEQUENCES

### *9.6.1 Monetary policy*

A CBDC would strengthen the Norwegian central bank's ability to use monetary policy. Overcoming the ZLB would allow more flexibility in situations where lowering the interest rate below this floor is needed. In an attempt to stimulate the economy directly, implementing helicopter money could serve as an alternative to QE. However, this has been unnecessary thus far. Price level targeting would most likely be more stable than inflation targeting, which could offer the Norwegian economy a more stable forecast of future price levels. The central banks' policies, such as lenders of last resort and deposit insurance, could become more efficient if needed. The possible substitution from NOK to cryptocurrencies is a difficult problem to tackle, but a CBDC might offer some incentive to use the national currency instead of other currencies, especially if it is interest-bearing.

### *9.6.2 Commercial banks*

There is a reason to believe that there could be a modest contraction in the Norwegian commercial banking sector if the CBDC were interest-bearing to the point of directly competing with bank deposits. However, through increasing deposit rates, the commercial banks should be able to keep most of their customers. Norwegian commercial banks offer loans and deposits to their customers, but they also provide a variety of other services. In Norway, the use of these additional services is commonplace. Therefore, banks would most likely remain an essential part of the economy. As long as deposit insurance and lender of last resort is in place, there seems to be little to no reason to prefer an interest-bearing CBDC instead of a bank deposit. However, crises can cause a modest shift away from bank deposits. Innovation in FinTech could be a threat, especially with the introduction of PSD2, but the potential impact is unknown. The total effect of implementing a CBDC is hard to measure.

The banking sector will likely change in response to the new economic climate to remain competitive.

### *9.6.3 Payment market*

Based on the current technology in Norway, a CBDC would most likely not provide a significant improvement in terms of speed. The main benefit would be the resilience a blockchain version would provide. In the event of a malfunction of the current system, a CBDC would most likely still function as long as electronic devices are not affected. While the payment systems in Norway would not see a significant change in terms of speed or settlement time, it opens the possibility for a new set of services. Micropayments could lay the foundation for new businesses, offering services that are currently out of reach. The FinTech sector could thrive on opportunities from such an advance in technology, but to what extent is unknown. If the system were to be open in the sense of offering an easy way to expand on the technology, then in conjunction with the introduction of PSD2, the FinTech sector could offer new and specialized payment alternatives.

## 9.7 THE IDEAL IMPLEMENTATION IN NORWAY

Based on the analysis and the discussion above and with the current landscape of Norway in mind, implementing a CBDC can be done in various manners. A register-based solution seems to be the ideal implementation as it would be the most similar to current cash and is unlikely to alter the mandate of the central bank. An indirect account-based solution is also possible. However, due to the lack of legislation on this technology in Norway and the increased competition associated with this approach, it would not be viable. The two considered blockchain structures offer different degrees of decentralization. To take full advantage of the benefits of blockchain, a permissionless and open ledger can be utilized and mitigate some risk through identification measures. If the central bank finds it necessary to restrict the read access, then a restricted access protocol is a viable option. A structure similar to RSCoin might be easier to implement but does not offer as many benefits over the current system, as the decentralized option. Therefore, a permissionless open distributed ledger is the preferable choice, built with a token-based register solution.

# 10. CONCLUSION

The possible implementation of a CBDC is under consideration in many countries around the world. As cash use is diminishing and cryptocurrencies continue to increase in usage, there is a need for an alternative to fiat currency. Through a systematic literature review, this thesis has examined and synthesized the most central research on this subject. The first consideration was regarding the taxonomy and motivations for the implementation of a CBDC. Furthermore, in Chapters 6 through 8, an examination of monetary policy, commercial banks, and payment services was conducted. The final section considers the best possible CBDC implementation for Norway based on the knowledge obtained in the analysis. It attempted to consider the best construction for the Norwegian economy, and the possible effects this could have.

Monetary policy is a complex subject, and the possible effect a CBDC could have is hard to quantify. If a CBDC were to replace physical cash, then the current ZLB could be moved further into negative territory, increasing the effectiveness of interest rate policy. The efficiency of the strategy is uncertain, as the reviewed papers disagree on the usefulness of lowering the ZLB. Policies such as QE, could, to an extent, be replaced by the concept of helicopter money, a "one-off" injection of cash directly to the public. A register-based CBDC would offer an effective solution to the possible troubles associated with transferring the money to citizens.

Through price level targeting, the current inflation targeting could be replaced, and offer a more accurate prediction of future price levels. A CBDC could also affect the seigniorage a central bank earns through creating money. The potential effects would be mostly dependent on the construction of the CBDC. An interest-bearing design would likely be in higher demand, causing a larger volume of CBDC in the economy. However, as the seigniorage covers the interest, the total effects are dependent on the rate set by the central bank. New cryptocurrencies from private companies such as Facebook threaten the current monetary power of the central banks. A CBDC could be a possible response to incentivize the use of the national currency.

Commercial banks receive a large part of their funding from depositors. A CBDC constructed with an interest-bearing structure would act as competition to deposit accounts, as they traditionally offer relatively low-interest rates. The CBDC rate would act as a floor for how low the commercial banks can set their deposit rates. Commercial banks would likely increase the interest rate they offer, as a CBDC is more secure than a deposit. To finance an increase in deposit rates, implementing higher lending rates, cost reduction measures, bundling services together, increasing risk on investments, or more bank lending might be possibilities.

Digital bank runs are feared by the central banks, as the ease of moving funds away from commercial banks can result in liquidity issues in case of adverse shocks. A CBDC could increase the risk of this happening if there are no withdrawal limits in place. Other measures to reduce the possibility of bank runs is the central bank acting as a lender of last resort and offering deposit insurance. These strategies have proven to be effective in preventing bank runs, and would likely not change with the implementation of a CBDC.

A CBDC using blockchain could provide immediate settlements and provide more efficient peer-to-peer and cross-border payments than the current system. Through higher transaction speeds and fewer intermediaries, a CBDC could reduce costs. The combination of more efficient peer-to-peer and cross-border payments, along with lower costs, could improve the remittance process. As these transactions have high fees associated with them, a CBDC could change remittance transfers for the better.

One of the main benefits a blockchain offers is the resilience of a decentralized distributed ledger. Centralized systems have always been prone to attacks as there are often single points of failure. By distributing the nodes in the network, blockchains are tougher to bring down, as a coordinated attack on everyone at the same time is arduous. Altering the centralized systems is possible, while a blockchain offers a permanent record that cannot be changed. This immutability makes a distributed solution such as blockchain safer from fraud. A CBDC built with blockchain would most likely be safer than a system built on an existing centralized structure.

Building a CBDC on a blockchain could also increase financial inclusion. There is less technological infrastructure needed compared to more centralized solutions. Therefore, the emerging economies, which lack a robust technological infrastructure, could employ a CBDC built with blockchain to offer the public a safe and secure currency.

A register-based CBDC would likely be optimal in Norway, as it does not change the underlying function of the central bank. Through a blockchain, either based on commercial banks as mintettes or a more decentralized solution, the CBDC would be easily accessible and secure. Using mintettes is a more centralized option than opening the process of block producing to the public, and the final choice of blockchain structure is contingent on what degree of centralization the central bank would prefer.

The research on CBDCs is still mainly theoretical, attempting to analyze the consequences it could have on monetary policy, commercial banks, and payment systems. Through this thesis, the complexity of the subject has been apparent, and predicting future impacts of this new concept is extremely difficult. There are merits to implementing a CBDC, but not without potential concerns, especially for the banking sector. As economies are moving towards a cashless future, and with private cryptocurrencies at the brink of realization, the discussion on CBDC will be an essential part of central bank research in the years to come.

## 10.1 FUTURE RESEARCH

There are several aspects of CBDC not considered in this thesis that could warrant a closer look. This section will reflect on these and areas of interest for further research not assessed due to being outside the scope of the thesis question.

Blockchain is in constant change, with the limits for transaction speeds having changed several times within the months of writing this thesis. As stated, blockchain is still relatively new, and the real impact of this innovation is unknown. Hailed as a technological revolution like the internet before it, the full effects of blockchain are still a mystery. There have also been advancements in quantum computing, which could have the ability to break cryptographic keys and codes, almost nullifying the security aspects that blockchain now offers. Therefore, it will be interesting to see how DLT and quantum computing develops over the coming years and what effect this could have on CBDC.

Cross-border transactions were considered briefly in terms of how it could increase efficiency and speed. Central banks are in the preliminary phases of testing CBDCs in this area, and the full effect that this could have is not known. Further research could view the impact that CBDC could have on a country's imports and exports, and how international trade could be altered as a whole if CBDC were to become widespread. One could also consider if a CBDC would open countries' borders even more and lead to a higher degree of globalization.

Another aspect is how the general public would react to the implementation of a CBDC. In this thesis, many assumptions regarding this were made, given that the research in this area was limited. Borgonovo, Cillo, Caselli, and Masciandaro (2018) released a paper titled "Between cash, deposit, and bitcoin: Would we like a central bank digital currency? Money demand and experimental economics," which considered this aspect. It set up the possible experimentation to analyze the demand for a CBDC in consideration with three other forms of money - paper currency, banking currency, and cryptocurrency. However, the study has yet to be conducted, which led to the use of assumptions for how the public would react to a CBDC, especially considering the case for Norway presented in Chapter 9.

Finally, the scope of the paper was limited mainly to commercial banks without giving much consideration to other financial intermediaries. Therefore, the effects that a CBDC could have on investment banks and the financial market as a whole is somewhat lacking. It could be interesting to see how future tokenization of assets onto a blockchain could alter the bond and stock market. It might make the economy more rational and in line with prevailing theories within economics, possibly eliminating market imperfections.

Inevitably, CBDC and its potential implications for central banks, the economy, and people appear as a field of study with significant potential for future research.

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