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Transformative Effects of Tokenization and Wholesale CBDC on Bonds

An exploratory study of the technologies' interplay and disruptive effects on the bond market's value chain

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Abstract

Distributed ledger technology (DLT) and tokenization are emerging technologies with the potential to transform financial markets through digitization and programmability. Presenting assets as digital tokens on blockchain platforms, new pathways for improving trading, ownership transfer, and servicing become possible. This thesis explores the utilization of tokenization and DLT in bond markets and wholesale central bank digital currencies (CBDC).

The analysis is guided by the research question: ***How can tokenization and DLT-based wholesale central bank digital currency transform traditional bond markets and their value chain?*** Findings from existing literature and expert interviews show that bonds exhibit frictions, including manual processing and delayed settlement. DLT could reduce these inefficiencies by enabling atomic delivery versus payment settlement, automating manual processes, streamlining ownership tracking and asset servicing through smart contracts.

Realizing these opportunities requires modernizing not only the structure of the asset but also the cash leg of transactions. A potential DLT-based wholesale CBDC represents central bank-issued money natively compatible with tokenized asset settlements. With programmable tokens and wholesale CBDC, instant clearing, and atomic settlement become achievable on integrated platforms.

Key findings indicate potential efficiency opportunities in bond markets. However, quantifying forecasted cost reductions involves uncertainty. Consultancy estimates range from 24% to 43% savings, but realizing such gains requires overcoming complex barriers, including interoperability, transition costs, system integration, legal framework, and altering established intermediary roles.

For market participants, trusting unfamiliar DLT codes poses a barrier that could be reduced if central banks include the technology in CBDC solutions, given their trustworthiness in Western economies. This will likely involve financial regulation to ensure accountability, security, and stability. While the technology offers theoretical improvements, translating into real-world disruption requires overcoming integration hurdles. This thesis provides insights into the technological promises and adoption realities that must be addressed before DLT can transform bond markets.

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Abbreviations

AML – Anti-Money Laundering

BIS – Bank of International Settlement

CBDC – General central bank digital currency

DLT – Distributed Ledger Technology

ECB – European Central Bank

MiCA – Markets in Crypto-Assets Regulations

OTC – Over-the-Counter

PoS – Proof of Stake

PoW – Proof of Work

rCBDC – Retail central bank digital currency

RTGS – Real-Time Gross Settlement

T+X – Trade date plus x business days

T2S – Target2-Securities

wCBDC – Wholesale central bank digital currency

1. Introduction

Bitcoin is based on blockchain technologies and primarily aimed to introduce an electronic payment system based on cryptographic proof instead of trust. However, it is viewed as a speculative asset in today's financial markets, alongside other cryptocurrencies that emerged after Bitcoin. While Bitcoin enthusiasts believe it will eventually dominate the world's economy, it may instead be blockchain technology disrupting the economy. Blockchain is one of the most well-known forms of distributed ledger technologies, which are digitized and decentralized logbooks of record. It provides the consensus mechanisms that maintain the security of the blockchain by keeping an immutable record of all legitimate transactions on decentralized networks.

The consensus mechanisms of blockchain technologies address a limitation with tokenization. The essence of tokenization is to convert a real-world asset into a digital token. Before blockchain, the process and consensus of tokenization relied entirely on third parties for database management, leading to a cap of applicability. Early tokenization on the Bitcoin blockchain was challenging due to its limitations in transaction speed and programmability. The release of the Ethereum blockchain in 2015 enabled more complex asset tokenization via smart contracts, improving programmability and transaction speed. Smart contracts are self-executing programs stored on a blockchain that automatically runs when predetermined conditions are met. Tokenization creates an opportunity to disrupt how we see, trade, and keep our real-world assets in the future. By representing real-world assets as digital tokens, a new form of secure ownership, trading, and transfers of these assets are enabled. The increase in blockchain-based innovation has ignited particular interest within financial markets eager to leverage the technology.

Blockchain's security, immutability, and transparency have sparked interest across financial institutions for various applications. Both private and public sector entities are exploring its potential to transform financial markets. In recent years, blockchain projects aiming to digitalize asset trading and streamline settlements have emerged. However, volatility in the cryptocurrency domain has historically affected the success of these initiatives. Incidents like the FTX and Terra Classic USD collapse have negatively impacted trust in blockchain systems.

Public institutions like central banks and big financial institutions like J.P. Morgan, European Investment Bank, and UBS have taken on tokenization projects and adapted the technology to existing and new services. Tokenized deposits from J.P. Morgan and tokenized bonds from the European Investment Bank and UBS have proven the potential benefits of tokenization and blockchain technologies. Tokenization of assets in combination with a tokenized or DLT-compatible payment solution will allow the emergence of atomic delivery vs payment settlement, in contrast to the current T+2 settlement[1]. The future will show if the preferable payment solution for settling these types of transactions will be in the form of a stablecoin[2], tokenized deposit[3], or central bank digital currencies (CBDC).

The global attention towards CBDC has accelerated as central banks consider updating sovereign currencies for the digital age. According to McKinsey, 87 of the central banks in the world, accounting for 90% of global GDP, are exploring CBDCs (McKinsey, 2023). Most of the solutions being explored are based on DLT, where some are also looking at how CBDCs could interact with tokenization and DLT platforms. Our thesis delves into the complexity of this interplay, specifically within traditional bond markets.

We examine the potential of disrupting bond issuance, trading, custody, and asset servicing using tokenization and wholesale CBDC settlement. This thesis aims to explore the intersection of DLT-based wholesale central bank digital currency and tokenization, potentially unlocking efficiencies in the bond market. The research question of our thesis is:

How can tokenization and DLT-based wholesale CBDC transform traditional bond markets and their value chain?

Answering this research question requires examining frictions in the financial ecosystem, wholesale CBDC designs, tokenization mechanisms, and the interplay between the payment and the asset in DLT settlement.

However, there are limitations to our analysis, mainly because the technology has yet to be widely adopted. With no widespread deployment of tokenized bond platforms settled with

[1] T+2 refers to settlement two business days after the trading day.

[2] Stablecoin refers to cryptocurrencies whose value is pegged to different assets. Further explained in chapter 2.3.

[3] Tokenized deposits are digitizing deposits and transforming them into tokens on a blockchain. Explained in chapter 5.3.2.

wholesale CBDC, we lack quantitative data on actual market impacts. Our qualitative approach relies significantly on existing literature and expert opinions from interviews. The interviewees have diverse backgrounds and may not represent consensus views due to their potential subjectivity and biased opinions.

Assessing hypothetical future scenarios involves uncertainty. Even though the technology is being used in sections of various businesses, we are exploring its use for broader applications throughout the bond value chain. Additionally, academic literature often underestimates how difficult it is to integrate new technologies into complex existing systems. Therefore, we are cautious about drawing final conclusions about benefits and limitations before real-world functionality is proven and tested. Our goal is to advance conceptual understanding. But we cannot predict how or when this technology will become a reality given the practical difficulties.

Our thesis contributes to existing literature with an in-depth perspective into the mechanism and interconnections needed to unlock the potential for bond efficiency gains using distributed ledger technology and tokenization. By interviewing experts across central banking, financial markets, computer science, and tokenization consultants, their firsthand insights enlighten technical possibilities and adaptation challenges. The analysis goes beyond the study of tokenization or wholesale CBDC to consider the interplay between the two in the complex bond value chain. While DLT-based wholesale CBDC and tokenization offer theoretical efficiency improvement, translating this into real-world disruption requires overcoming various integration barriers. This thesis provides a valuable framework for conceptualizing technology while grounding these promises in the realities of financial markets, legacy systems, and potential risks.

The rest of our thesis is organized as follows: Chapter 1 introduces the background and motivation of the chosen research question. This part gives a brief introduction to some key concepts in the topic and an explanation of the research question.

Chapter 2 contains the theoretical background of this thesis. To understand how DLT-based wholesale CBDC and tokenized bonds can affect the bond market, theoretical concepts must be elaborated on beforehand. Concepts like blockchain, distributed ledger technologies, tokenization, smart contracts, money and payment solutions, stablecoins, CBDC, and tokenized and traditional bonds.

Chapter 3 introduces the methodology and outlines why we chose an exploratory deductive approach. This part explains how the search of literature and interviews helped us find a solution to the research question. Concerns related to bias and ethics were raised, and the analysis of the data gathered from the interviews is thoroughly explained.

Chapters 4-7 analyze the topics discussed during the interviews and how they relate to published literature. Chapter 4 analyses the benefits and use cases of a potential retail CBDC. The challenges and concerns regarding trust and understanding were brought up, together with how the implementation of retail CBDC could look.

Chapter 5 analyzes the potential of a DLT-based wholesale CBDC. Factors considered are how settlement, cross-border payment, and programmability can influence the economy. Concerns about interoperability challenges are brought up and analyzed. Alternatives to DLT-based wholesale CBDC are explored.

Chapter 6 explores both the current and tokenized bond market. We have analyzed bottlenecks in the current bond market and explored the benefits and challenges that tokenized bonds will introduce.

Chapter 7 introduces a small case where we aim to elaborate on the cost benefits of transitioning to tokenized bonds using wholesale CBDC. The case goes through the entire value chain of bonds and analyzes key benefits tokenization could introduce.

Chapter 8 contains a discussion part where the interplay between DLT-based wholesale CBDC and tokenized bonds is explored. Discussions around whether settlement efficiencies are needed or not were conducted here. Interoperability concerns and benefits are explored, and the feasibility and potential of new risks are elaborated on.

Chapter 9 contains the conclusion to our research question and our final thoughts on the topic. This chapter also includes a section on how we imagine future research could explore this topic further. The weaknesses and limitations of this thesis can be found in this chapter.

2. Theory

2.1 Blockchain

Blockchain technology is the cornerstone of many digital cryptocurrencies. Even though the concepts of distributed ledger and blockchain were discussed in 1976 in a whitepaper named "New Directions in Cryptography," the technology emerged in 2009 with the release of Bitcoin. Bitcoin, created by the presumed pseudonymous person Satoshi Nakamoto, is the most recognized and prominent cryptocurrency built using blockchain networks (Sarmah, 2018). The blockchain network is simply a database for all users in which there are sets of recordings called blocks with timestamps linking them to the previous block forming a chain, therefore given the name "blockchain" (Hashemi Joo et al., 2020, p. 716).

One distinguishing feature of blockchain technologies is its decentralized nature, which eliminates the need for central authority. When introduced through Bitcoin[4], it was an innovative use of the technology, aiming to solve the problem of double spending – the challenge of ensuring that a digital token is not used more than once. Blockchain technologies have many use cases and can be used to make data immutable. However, they are most known for their prominent way of maintaining a secure and decentralized record of cryptocurrency transactions. Before blockchain, verifying the legitimacy of a transaction required central authority, such as banks and regulated financial institutions. With blockchain technologies, two individuals, humans, or organizations, could make digital transactions without a trusted intermediary. It facilitates secure peer-to-peer transactions across a decentralized network where each participant´s computer, or node, contains a copy of the blockchain without needing a central database. When utilizing cryptographic keys for security, transactions are grouped into blocks and chronologically linked using hashes that ensure integrity and continuity. Nodes

[4] Bitcoin is a virtual currency designed to act like money outside the control of any third party. Ownership of Bitcoin means owning a Bitcoin address, which has a balance recorded on the blockchain. The owner of this address controls the Private Key and is allowed to sign transactions using these Bitcoins. The Bitcoin blockchain holds the record of every Bitcoin transaction ever made.

are the moderators used to build up the network's infrastructure and are used to verify that transactions are correct and effectively proceeded (Miah, 2020).

2.1.1 Consensus mechanisms

To settle transactions between two parties, they must come to consensus. Consensus is defined as a general agreement about something. This consensus is automated within the blockchain. Algorithms within blockchain networks such as Bitcoin and Ethereum provide these consensus mechanisms. To make transactions on the blockchain, each network user has to use public and private key cryptography. The public key can be seen as a bank account number from which one can receive funds. The private key is secret to others and used to authorize transactions. The private keys are simply numbers that have been picked at random. The key gives the holder control over the funds secured by that key. The public key is calculated from the private key using irreversible elliptic curve multiplication. The public key K is calculated as K = k * G, where k is the private key, and G is a constant point called the generator point. Therefore, computing the private key k if you know the public key K will be as tricky as trying all the possible values of k (Antonopoulos, 2017).

One of the main benefits of blockchain technologies is the consensus mechanisms. A consensus mechanism is crucial to the blockchain system, providing efficient, distributed agreement on the ledger's state. It can replace slow human verification with a faster and automated process. The mechanism is a cryptographic program that helps to achieve agreement on a database state in a distributed network. The mechanisms work by creating and verifying unique alphanumeric strings called hashes. When all nodes on the network produce matching hashes, consensus is reached (Frankenfield, 2023).

There are two main consensus algorithms: Proof of Work (PoW) and Proof of Stake (PoS). PoW, used by Bitcoin and Litecoin, requires nodes to add new transactions to the blockchain. It involves solving an encrypted hexadecimal number. A network of miners does the verification. The miners provide computational effort (work) to engage in hashing functions randomly. They will do this by hashing functions until an output arrives with the correct minimum number of leading zeroes (Nevil, 2023). PoW enables secure peer-to-peer transactions without a trusted third party. It requires a significant amount of energy and computational effort to validate transactions.

PoS protocols require traders to stake their cryptocurrencies as collateral, locked up in a deposit. If a trader adds a transaction to the blockchain and the other validators on the network do not consider it a valid transaction, they can lose a portion of what they staked. In Ethereum PoS, the validator on the network stakes their ETH as capital into a smart contract on Ethereum. Ethereum is a blockchain and distributed platform, while ETH is the cryptocurrency used on the Ethereum platform. The validator on the platform is responsible for controlling that the new blocks are valid and creating new blocks themselves. If they propose multiple blocks, while they should only send one or send conflicting attestation, some or all their staked ETH can be destroyed (Ethereum, 2023).

Blockchain consensus mechanisms are important to understand. It gives the foundation for understanding how the trust in the transactions using the technology is constructed without any centralized third-party intermediaries.

2.1.2 Types of blockchain

Public blockchain networks are permissionless. Each user can access two sets of keys, one public and one private. The public key is accessible to everyone on the blockchain; this is the address to send/receive, for example, Bitcoin, and makes all transactions transparent by tracking the public key address. The private key works in a similar way as a password. Transferring cryptocurrencies will broadcast the transaction to the entire public blockchain network.

Users called “miners” on the Bitcoin network must validate the transaction using a complicated mathematical cryptography computation. The validation uses computer processing power to decrypt the message and usually takes between 10 and 20 minutes (Hashemi Joo et al., 2020, p. 716). After validation, a new block on the blockchain containing information from this and all previous transactions is created. There are multiple pros and cons of using a public blockchain. Some pros worth mentioning are transparency, openness to the public, immutability, and rewarding the ones providing computer power. However, there are two distinct cons to the public blockchain. One is that it is unsuitable for sensitive and proprietary data and could encounter scalability problems and a transaction slowdown. The public blockchain could experience a slowdown due to reaching the capacity limit because it is open to anyone (Jha, 2023).

In contrast to the public blockchain, the private blockchain is permissioned. This means that only some people or organizations can access the blockchain. The blockchain is issued or controlled by a company or organization, and they can grant access to the network and enable the permitted users to read or write on the blockchain network. Compared to the public blockchain, the private ones are smaller and, therefore, faster in transaction speeds. The network's security is higher because only selected ones can write code on the blockchain. Some might say that a con for private blockchain is that it needs to rely on third-party management systems and is, therefore, only partially decentralized (Jha, 2023).

A hybrid blockchain combines some aspects of both public and private blockchains. An entity controls the blockchain and gives an organization control over which participants are granted access to some specific data stored in the blockchain, and they also decide what data should be open to the public. The fourth type, consortium blockchain, is designed through a collaboration between entities that want to use a decentralized network to collaborate and meet the challenges of an industry. It enables companies to join an already established data structure instead of starting from scratch. For instance, if a group of banks come together and use a consortium blockchain to share required information about the creditors, they could allow another bank to participate. The information of interest can be accessed through the distributed ledger (Banerjee A. , 2022).

2.1.3 Distributed ledger technology

All blockchains are distributed ledger technologies (DLT), but not all DLTs are blockchains. DLT refers to a decentralized ledger or database distributed across multiple participants on a network. This technology allows transactions to be recorded, shared, and synchronized through consensus mechanisms between parties (Ugarte, 2018).

A DLT can be compared to a traditional bank book record as they both maintain records of and validate transactions. They both aim to provide a secure way of conducting financial transactions and storing assets. DLTs have features traditional banks do not offer, such as settlement outside operating hours, enabling programmability, and direct transactions without intermediaries. DLTs combine three main technologies to provide these features: peer-to-peer networks, cryptography, and consensus algorithms (Ugarte, 2018).

2.1.4 Tokenization

In the context of blockchain, a token is a digital representation of a tangible asset on the blockchain. Tokenization is the transformative process of representing a real-world asset as a token. It is a relatively new model that digitizes traditional tangible assets such as real estate, commodities, and financial assets like equity and bonds. These tokens can exist separately on a blockchain or off-chain records in a centralized security depository. The tokenization enables asset holders and market makers to access blockchain technology benefits, for instance, 24/7 operations, data availability, and atomic settlement. Tokenization also offers programmability, which means that one can include code into the token and enable the token to engage with smart contracts, giving the asset a higher form of automation. Tokenization involves four fundamental steps to issue and distribute the token (Banerjee et al., 2023).

First, before tokenizing the asset, one needs to identify the structure of what is to be tokenized. Different types of assets need various structural forms of tokenization. It also helps to know what regulatory frameworks will apply to the asset.

Secondly, the asset needs to be secured by a custodian or a licensed trust company. The token issuer on the blockchain then embeds functionalities into the code to execute predefined rules of the token. To embed these functionalities, the issuer often chooses a token standard based on ERC standards like ERC-20 or ERC-1155 (explained in chapter 2.1.5). The issuer must also select a blockchain network and the functions embedded in the token.

Thirdly, the token can be distributed to the end investor through traditional channels or digital-asset exchanges. For the investor to hold the digital asset, it must set up a digital wallet, while the physical asset equivalent remains immobilized with the traditional custodian. Depending on the issuer and the type of asset, the owner might enlist a secondary trading market for the tokenized asset to create liquidity for the assets postlaunch.

The fourth step is that the tokenized assets require ongoing servicing once they reach the end investor. This includes taxes, accounting reporting, and periodic net asset value calculations. This servicing differs from asset to asset, but when the assets are all digital, it will be easier to service them than physical assets (Banerjee et al., 2023).

One of the most profound impacts that tokenization of assets enforces is immutable transparency and accountability by offering a clear history of transactions and immutable

records of ownership of the assets provided by the smart contract. All information is accessible on the shared ledger distributed on peer-to-peer network nodes (Kumar et al., 2022).

Tokenization streamlines transaction efficiency by enabling faster, cost-effective transactions through automated exchanges. This will reduce the friction of a single know-your-customer process across all platforms by linking the users' wallets to the blockchain. It will reduce or remove the need for third-party custodians and depositories over the asset's lifetime and introduce atomic settlement in contrast to T+2, the standard for traditional assets (Kumar et al., 2022).

Tokenization of assets can also fractionize high-ticket instruments. It could open new and broader pools of investors, bringing market liquidity. It also allows trading on assets before maturity, enhancing market flexibility.

2.1.5 ERC standards

There are different types of tokens, mainly fungible and non-fungible tokens. Fungible tokens are divisible and not unique. Fungible assets could be like fiat currencies, where one dollar equals one dollar independent of where you are. Fungible tokens can be included in a payment system, such as the dollar or a store of value in terms of an asset or part of an asset. A non-fungible token is unique and non-divisible. It represents the ownership of a non-replicable item such as artwork, real estate, or an item where there cannot be another of the same kind due to its specific features or data.

Fungible tokens have a property that makes each token the same in type and value as another token on the identical blockchain. When fractioning a traditional asset like a bond certificate into a given number of tokens, for example, 1000, each of those 1000 tokens on the blockchain is fungible. It means every one of the 1000 tokens is like another and has the same features and value.

Tokenization on the Ethereum blockchain uses different standards of what rules and features they need to follow. These standards are called ERC standards. Tokens can be based on different ERC standards regarding what type of token one wants to create and what rules and conditions the token should have. The best-known standard for fungible tokens is the ERC-20 standard. ERC-20 stands for Ethereum Request for Comment number 20. In 2015, Fabian

Vogelsteller introduced the ERC-20 standard. This standard outlines how to program tokens compatible with Ethereum's smart contracts (Ethereum, 2023).

The ERC-20 could be seen as a list of functionalities and events that must be implemented into the token for the token to be considered ERC-20 compliant. The standard has functionalities like transferring tokens from one account or wallet to another, reviewing the current token balance for an account and the total supply of tokens on the network, and approving whether a third-party account can send a token amount. The functions are programmed into the token and provide a standard interface. The interface reduces the confusion if each token is programmed based on different methods (Ethereum, 2023).

2.1.6 Smart contracts

One helpful feature of blockchain technologies is the implementation of smart contracts. A smart contract is simply a computer program stored on a blockchain that will be executed whenever the predetermined conditions are met. By running on a decentralized blockchain rather than a centralized server, the smart contracts allow multiple participants to conclude on the same shared results in a tamper-proof manner (Chainlink, 2023). Smart contracts are usually used to automate the execution of an agreement for the participants on the contract to be 100% certain about the outcome. When the smart contract is executed, it is instantaneous and without the need for any intermediaries (IBM, Unkown date).

Inside a smart contract’s code, there are written simple “if/when – then” statements. These statements could, for example, be a release of funds, payment of dividends, coupons, principal value, or interest to a pre-determined participant. When the condition is met and the transaction is completed, the blockchain the smart contract is built upon is updated and immutable (IBM, Unkown date). Most smart contracts are immutable, and disagreements on the smart contract's terms must be addressed before creation. However, there exist forms of upgradable smart contracts where, for instance, fixing bugs, improving functionality, and code optimization can be addressed (Pratap, 2022). To satisfy the needs of the smart contract, as many conditions as needed can be programmed into it before creation; therefore, the contracts have a significant form of flexibility.

A smart contract is executed immediately, without any paperwork, and has high accuracy. No third parties or intermediaries are involved, the time delay is removed, and additional fees

vanish. The information in the contract is transparent and available for all permitted participants. Therefore, there is no need to question whether the contract terms have been tampered with for participants' benefit. The records of the transactions are encrypted, so the security is considered high (IBM, Unkown date).

2.2 Money and Payment Systems Today

Money, a fundamental unit of exchange and a store of value, has continuously changed throughout human history, parallel with changes in needs and technological developments. Recently, money and means of payment have appeared in different forms. The leading monetary solutions have been credit/debit cards, cash, bank transfers, electronic payments, and, most recently, cryptocurrency.

Regardless of form, money has three different purposes. Money acts as a medium of exchange, meaning a means of payment with a set value that everybody believes in. Additionally, money is a unit of account for pricing goods and services. Lastly, money is a store of value (European Central Bank, 2017). The purpose of money is the same for all individuals, businesses, and government bodies.

In 2022 the European Central Bank (ECB) conducted a survey to better understand trends in consumer payment habits. The survey states that although cash payments were the most frequent means of payment in the euro area, they were used less than card payments in terms of the value of payments (European Central Bank, 2022). Through the ECB´s findings, it becomes clear that a shift in means of payments will be more apparent soon. Consumers are turning away from traditional payment methods like cash and prefer more convenient solutions like card payments, and contactless payments and payment apps are on the rise.

2.2.1 Real-time gross settlement systems

In addition to innovation and changes in payment in retail settlements, there have recently been innovations in interbank payments. Interbank payments using real-time gross settlement (RTGS) systems, which allow real-time settlements, minimize high-value risk and ensure efficient cross-border settlements. The Eurozone has created Target2, now replaced by T2 in March 2023, which has emerged from the TARGET initiative system. The T2 system handles RTGS transactions for central banks, commercial banks, and financial institutions. The system

handled in 2021 on average 373.468 payments daily, averaging a euro amount of 1.877 billion. 99,98% of transactions were processed in less than a minute during business days between 07.00 and 18.00 (European Central Bank, 2022).

The improvement of the RTGS system has helped shorten the settlement cycle for securities, reducing the time it takes to transfer ownership and payment between the seller and buyer when settling securities such as stocks, bonds, funds, etc. Traditionally, this settlement took up to five business days, meaning that when a security purchase took place, it took five days from making the payment until the individual had ownership over the security (Securties and Exchange Commission, 2004). In the 90s, the T+3 settlement cycle was introduced. T+3 reduced some risks that the financial market suffered from the T+5 cycle. This includes risks regarding price plunges and volume soars. With more extended settlement periods, the risk of investors being unable to cover their transactions increases. The current settlement period is the T+2 cycle for most developed markets, further reducing settlement risk when buying or selling securities.

For 23 European countries, instant settlement and efficient cross-border settlement of securities with low settlement risk have existed for years. The Target2-Securities system (T2S) allows for a more seamless securities settlement for the membership countries than traditional RTGS systems. The market participants in T2S have a securities account with one of the central securities depositories and a dedicated cash account at one of the central banks connected to the T2S platform (European Central Bank, 2023). The market participants can settle securities using the Euro or the Danish Krone.

In the United States, there is currently a move towards T+1 settlement, meaning that most settlements will be closed within one business day after the trade. The estimated start date for the new cycle in the US is in the spring of 2024. The T+1 settlement will provide the U.S. market with more liquidity and less settlement risk. There are, however, some challenges with the upcoming T+1 cycle. One pressing challenge is that Europe is not yet ready for T+1 (BNP Paribas, 2023). While the T2 system creates a common interbank transfer for the eurozone, the diverse markets with different regulations and settlement environments make it challenging to implement T+1. Introducing T+1 in the US might create an advantage for US-based investors. In contrast, European investors in the US market might experience a disadvantage, which could also open an arbitrage opportunity (BNP Paribas, 2023).

2.2.2 Central banks

"The art of central banking has evolved over time and continues to change, but the principles of sound central banking practice have remained largely unchanged" (Downes & Vaez-Zadeh, 1991, p. 5). Throughout history, central banks have played an essential role in society and politics, primarily steering towards financial stability. Other responsibilities include but are not limited to issuing loans to commercial banks, overseeing interbank markets, defining monetary policy, and regulating money in circulation (Santander, 2023). Although central banks are working towards financial stability, not all type of money is backed by or the responsibility of central banks. Table 1 gives an overview of whom different variants of money are backed by.

Type of money and currencies	Backed by
Bank deposit	Commercial banks
Cash	Central banks
Cryptocurrency and stablecoins	None
Central bank Digital Currency	Central banks

Table 1 - Backing of money and currencies

2.3 Stablecoins

Bitcoin and most other cryptocurrencies are decentralized financial networks, meaning no responsible parties govern these currencies. This contrasts with centralized financial systems, i.e., banks, central banks, etc. Some authorities can access and control most aspects of the product in the centralized systems. There is no central controlling entity of Bitcoin, for instance. All the trust and control are based on the technology it is built on. However, the technology is not the only factor determining whether a project is successful or not. Many cryptocurrencies have failed, most of them not that widely adopted. Other more famous projects have also collapsed, explained three paragraphs below. This shows that trust in decentralized systems faces challenges, and it is difficult to develop complete trust.

Stablecoins are often pegged to a national currency and, most commonly, to the USD. Stablecoins come in the form of centralized and decentralized. Even though most stablecoins are pegged to the USD using different techniques and collateralization, their reference value can also be another fiat currency, commodities of goods, or other cryptocurrencies. They are used primarily to make crypto asset transactions more effective. Stablecoins are tokens operated on a blockchain or distributed ledger. They differ from traditional digital records of money in two parts. Firstly, they are cryptographically secured, allowing atomic settlement without double-spending or intermediaries. Another advantage is that it allows for 24/7 operations and settlement of transactions. The second part where stablecoins differ is their programmability. Due to the DLT standards that stablecoins are designed on, they can provide a feature known as "composability." This implies that they can act as independent units working with automated smart contracts. This collaboration can pave the way for innovation and development in the payment and financial services (Liao & Caramichael, 2022).

2.3.1 Public reserve backed

There are different forms of stablecoins based on how they are constructed, what they are backed by, and whether they are public or private. The most significant portion of stablecoins is called "Public reserve backed." These stablecoins circulate on public blockchains like Ethereum and Polygon. Reserve-backed stablecoins are also called custodial stablecoins. This is because they are issued by intermediaries that serve as custodial for cash equivalent assets and are restricted by financial regulations. These stablecoins use fiat as collateral, where the currency is held off-chain to maintain the stablecoins peg. Because of the cash equivalent assets, they can offer a 1 to 1 backing of the stablecoin liability, either in USD or other fiat currencies dependent on the fiat collateral. Custodial stablecoins represent the most significant portion of stablecoins that exist (Liao & Caramichael, 2022).

2.3.2 Algorithmic

The second form of stablecoin is public algorithmic stablecoins. Systems of smart contracts on public blockchains maintain the stability of stablecoins based on this technology. These stablecoins are designed based on the collateralized and algorithmic peg mechanisms. Usually,

the coins are minted[5] when a coin user deposits a volatile digital asset into the smart contract protocols of the coin. These digital assets serve as collateral, often as a volatile cryptocurrency. Because digital assets are typically volatile, the user of the stablecoin needs to provide digital assets worth more than 1 dollar to mint 1 dollar worth of the stablecoin (Liao & Caramichael, 2022).In May 2022, this form of stablecoin was hit hard by the public algorithmic stablecoin Terra Classic USD (USTC) crash. USTC was part of Terra's blockchain ecosystem, which contained a sister token named LUNA. USTC and LUNA formed an algorithmic stablecoin that aimed to maintain a value of 1 USD for each USTC by using LUNA to back up the USTC. When the value of USTC slipped below $1, panic among the holders was triggered, and people wanted to exit USTC by converting into LUNA. This led to hyperinflation in LUNA´s supply, which collapsed from $120 a coin to a price equivalent to $0 within a couple of days (Wind, 2023). $50 billion of the USTC and LUNA's market capitalization was eliminated. This also brought a considerable drop in the rest of the crypto markets, leading to a $400 billion reduction in market value, much because of reduced trust in the speculative assets in the crypto markets (CFI Team, 2022). This proves the potential instability of using digital assets as collateral compared to fiat collateral for issuing stablecoins, implying that stablecoins may not always be stable.

2.3.3 MiCA regulation

The USD-based stablecoin market cap is roughly 99%, and the remaining 1% comprises the non-USD-based stablecoins pegged to fiat. While regulations on the U.S. stablecoin market are still in progress, the EU has recently announced new regulations targeting stablecoins and crypto assets. The comprehensive regulation named MiCA Regulations has emerged. MiCA stands for Markets in Crypto-Assets Regulations. It defines crypto assets as “a digital representation of value or rights which may be transferred and stored electronically, using distributed ledger technology or similar technology” (Häring et al., 2023). The MiCA regulations are being implemented and will be taken into action within the close of 2024. MiCA aims to replace national regulations within the EU with one unified regulation that accounts for all EU nations. Another aspect of MiCA is that it seeks to set clear rules for

[5] Minting coins are the same as producing new coins and adding them to the blockchain's total supply.

crypto-asset issuers that are not covered by the current financial regulations (Legal Nodes Team, 2023).

Under MiCA stablecoins are referd to as Asset-Referenced Tokens (ART) and Electronic Money Tokens (EMT). ARTs have to be backed by two ore more fiat currencies, or by any number of non-currency assets. EMTs are backed by a single one single fiat currency (Helm & Katz, 2023). The reseves assets for ART are under adequate custody policy where the reserve assets needs to be hold be a third party custodian, either a crypto asset service provider, authorized credit institution, or authorized investment firms. To protect holders of these ARTs, the issuer should only invest reserve assets in secure, low-risk assets with minimal market, concentration and credit risk. All profits or losses from these reserve asset investments should be borne by the issuer, and not the holder of the ART (European Union, 2023).

Algorithmic stablecoins will be banned under the MiCA regulations, and the issued fiat-backed stablecoins must be backed by a liquid reserve with a 1:1 ratio to the fiat currency (European Union, 2023). Issuers are restricted by specific requirements, such as that they need to establish a reserve of assets that are separated from other assets and held by a third-party custodial.

2.4 Central Bank Digital Currencies

The rise in popularity and the possibilities DLT and blockchain-based digital currencies provide have led multiple nations to explore the potential of a central bank-issued "cryptocurrency," Central bank digital currency (CBDC). CBDC is a new form of digital currency, which would be a liability to a central bank and not to a commercial bank as money in bank accounts is. In short, CBDC is a currency that would work the same way as cash, only digitally. According to McKinsey, as of March 2023, 87 central banks, representing more than 90% of the global GDP, are exploring the possibilities of the CBDC (McKinsey, 2023).

CBDC will hold the same value rate as the nation's current currency, i.e., one digital Euro would equal 1 Euro. One might argue that such a digital currency already exists in the form of cryptocurrency called stablecoins, as discussed above. The difference between stablecoins and CBDCs is that CBDCs are backed by the central bank and are guaranteed by the central bank to hold the same value as the nation's currency, but stablecoins are not. While stablecoins

often are pegged to safe assets such as cash, money market funds, or commercial papers, making them less volatile than other cryptocurrencies, they are not immune to changes in the market. Terra Classic USD and LUNA are examples of algorithmic stablecoins who lost all their value due to their lack of backing following a market crash (KPMG, 2022).

2.4.1 Retail and wholesale CBDC

CBDCs are intended to be represented in retail CBDC (rCBDC) and wholesale CBDC (wCBDC). Most of the central banks in the world exploring CBDC are mainly exploring rCBDC. This will provide the public with continued access to central bank money in a digital form in addition to paper money access in the form of cash. Cash has recently declined in Western countries, and the need for a digital alternative backed by central banks exists. The central banks want to preserve their role in providing the public with a safe and trusted medium of exchange by issuing a retail digital currency. CBDC will, in the same way as stablecoins, be distributed and kept by individuals and businesses in electronic wallets that allow them to send and receive instant payments at any time, nationally and internationally, with and without an internet connection (Mandeng, 2021).

Retail CBDC will include the use case of programmable payments or smart payments. Smart payments will enable you as a buyer to decide on what conditions must be fulfilled before the money transfers from your wallet to the receiving wallet. You can, for instance, program the money to finalize the payment if, and only if, you have received the product and the product is in the expected condition. If rCBDC becomes a legal tender, one can use it in all situations involving payments. Using rCBDC will be independent of banks' payment solutions, making the system less vulnerable (Norges Bank, 2023).

A wholesale CBDC refers to using CBDC when settling interbank transfers using central bank digital money. A type of wCBDC has existed for decades. Central bank money in a digital form is currently being used for transactions between banks, and systems like TARGET2 and T2 wholesale payment systems allow for real-time gross settlement between banks in the Eurozone (European Central Bank, 2023). Nevertheless, the settlement time for trading securities is still at T+2 except for the countries participating in the T2S settlement system. Here, wCBDC projects try to make settlements of securities and cross-currency payments more efficient and safer. Many believe wCBDC should be based on distributed ledger technologies, but it can also be based on other technologies. For instance, the TARGET system

in Europe uses a centralized ledger for settling wholesale digital transactions (Panetta, 2022). The stakeholders that would use a DLT-based wholesale CBDC are narrow, and banks are already using digital central bank infrastructures for settlement today. DLT-based wholesale CBDC brings the potential to improve the settlement of cross-border and cross-currency transactions. However, research on the total benefits compared to existing technologies needs further exploration. The central banks want to be prepared if market players wish to adopt DLT-based solutions for wholesale and security settlement (Panetta, 2022).

2.4.2 Use cases

There are multiple reasons why different nations are interested in developing their own retail CBDC, and other motivations depend on the nation's economic situation. For underdeveloped nations, rCBDC could help with financial inclusions for those with limited or no access to the banking system in the retail case. In addition, it would be a welcomed alternative to cash payments when cash payments are declining due to its impracticality. Another advantage to rCBDC is that central banks would have a new way of better controlling monetary policies by having more direct control over money. With rCBDC, central banks can track trends in spending and consumer behavior in real time, making it easier and more effective to create preventative measures in their monetary policies (Karam, 2023).

For the financial industry, there are multiple advantages to implementing wholesale CBDC. Wholesale CBDC reduces the need for intermediaries in a payment process, increasing transaction speed and reducing transaction costs (Karam, 2023). With the right technology, wCBDC could open up for more efficient settlement of security trading. CBDC could also benefit cross-border transactions, making it cheaper and more effective. Standardizing retail and wholesale CBDC across nations can streamline cross-border transactions. Project Icebreaker, a collaboration between the central banks of Norway, Sweden, and Israel, has researched the possibilities of such a standardization of cross-border transactions (Bank of International Settlement, 2023). The project successfully completed transactions across the three countries' borders, swapping between their currencies. Project Icebreaker attempts to solve the long-lived problems with cross-border payments, which have been plagued with high costs, low speed, limited access, and poor transparency (Norges Bank, 2022).

2.5 Bonds

Bonds are a helpful tool for governments and corporations when they need capital. When an investor[6] buys a bond, it´s the same as the investor lending money to the bond issuer. The bond is simply a loan that pays interest to the investor. Still, unlike a bank loan, the repayment of the principal value is made at the bond's maturity and not in periodical deductions. The interest rates of a bond may be less than the bank loan, and if the corporation needs more capital than the bank is willing or able to provide, a bond is an option. And if the corporation wants long-term financing with fixed and predictable interest payments, bonds are preferable (PIMCO, Unknown Date).

Bonds are crucial for some investors to include in their portfolios. It offers multiple benefits to the investor, such as capital preservation, income generation, diversification, and a hedge against economic downturns. Unlike equity, bonds ensure the repayment of the principal value at the maturity date, making them attractive for investors wanting to safeguard their capital and appealing to investors who need to meet obligations in the future. In addition, bonds often have higher interest rates than short-term bank deposits and provide a steady income stream (Schmidt, 2023).

The market capitalization of the global bond market in 2020 was estimated to be $128.3 trillion, whereas China and the U.S. make up the most significant capitalization. The greatest portion of bonds is government Sovereign, Supranational, and Agency (SSA) bonds, with a capitalization of about 68% of the total bond market, and corporate bonds taking up the rest of the 32% of the bond market capitalization (ICMA, 2020), even though there are different types of bonds as well.

2.5.1 Corporate bonds

Corporate bonds are ´issued by a company that wants to raise money. Corporate bonds can have fixed, floating, or zero-coupon interest. For fixed and floating the coupons are paid

[6] Investors in bond markets can be corporations, governments, or private investors.

evenly throughout the bond's lifetime, but for zero-coupon bonds the interest is paid back together with the principal amount (SEC, 2013).

The risks associated with corporate bonds are correlated with the bond's maturity timespan. Increased maturity time increases the company's risk of failing to make timely repayments. To compensate for this, bonds with long maturity often pay higher interest rates. Credit rating agencies rate corporate bonds based on the financial strengths of the issuer and the risk of the company or bond default. These ratings consider the bond as investment-grade or non-investment-grade. Investment-grade bonds do receive higher ratings from the agency and are safer investments. Non-investment grade bonds are less likely to be paid on time and are also called high-yield or speculative bonds (SEC, 2013). The different ratings of bonds illustrated in Figure 1 display Moody's Rating, S&P Rating, and Fitch Rating with the commentaries from Wolf Stree.

New Constructs Rating	Moody's Rating	S&P Rating	Fitch Rating	Wolf Street Commentary
Very Attractive	Aaa	AAA	AAA	Prime
	Aa1	AA+	AA+	High grade
	Aa2	AA	AA	
	Aa3	AA-	AA-	
Attractive	A1	A+	A+	Upper medium grade
	A2	A	A	
	A3	A-	A-	
Neutral	Baa1	BBB+	BBB+	lower medium grade
	Baa2	BBB	BBB	
	Baa3	BBB-	BBB-	
Unattractive	Ba1	BB+	BB+	Non-investment grade speculative
	Ba2	BB	BB	
	Ba3	BB-	BB-	
	B1	B+	B+	Highly speculative
	B2	B	B	
	B3	B-	B-	
Very Unattractive	Caa1	CCC+	CCC	Substantial junk
	Caa2	CCC		Extremely speculative
	Caa3	CCC-		Default imminent with little prospect for recovery
	Ca	CC	CC	
		C	C	
	C	D	D	In default
	/			
	/			

Figure 1 - Bond ratings (New Constructs, 2023).

2.5.2 Government bonds

While corporate bonds provide financing for companies' ongoing projects or expansion of their business, government bonds provide the financing of infrastructure projects or support development for the public. This is a way of supporting spending without raising taxes. These government bonds are sold to investors much the same way as corporate bonds but are also considered more liquid. These bonds are considered less risky than corporate bonds due to the government's inflow of money from their claim on taxes. This results in lower yields for

government bonds. Government bonds can range from one to 30 years until maturity, while corporate bonds often range from three to seven years, with some less and some up to 10 years (Australian Bond Exchange, 2023).

2.5.3 Value chain

The way from deciding to issue a bond until maturity for a traditional corporate bond issuance is a complex procedure for financial intermediaries and stakeholders in the value chain. The value chain comprises six main categories: issuance, trading, clearing, settlement, custody, and asset servicing. Firstly, the bond must be issued by the issuing corporation, and then it needs to be traded for the issuer to raise the capital it wants. After the bond has been sold to a buyer, the process goes to the clearing and settlement process, where the transactions are verified, and the final settlement of the transfer of the security from the seller to the buyer in exchange for financial compensation, often in the form of a currency. After the security has been transferred to the buyer, the buyer needs to use a custodian who acts as an asset safekeeping intermediary to ensure that the security holdings are always equivalent to the security value. The final category is the asset servicing. This maintains that the bond terms are followed during the bond's lifetime. For instance, these intermediaries keep track of taxations and coupon payments to the bond owner (Ramachandran et al., 2022).

Issuance and trading

During the issuance process, the issuer must talk to its bank so that the bank can control if the corporation meets the requirements for a bond issuance. The bank recommends a rating agency that rates the bond regarding its risk and whether it is a secure or speculative investment. Before the bond is placed in the market, the issuer must go through a so-called “Roadshow.” This is where the issuer finds out what the market looks like and the interest in the company's risks. If the interest from investors is significant enough, the bond is placed on the market. The bank has advised the issuer on the conditions for the bond regarding price, and the bank and issuer agree upon the fees regarding the issuance coordination. When the day for market drop comes, the market conditions are checked, and if they are appropriate for the release, the issuance is announced to the market, and the “book” is opened to investors to place orders. When the bank closes the book, fractions of the bond are given to each investor based on the quality of the individual investor as well as the objective of the issuance. Then, the price is established, and the bond is listed on the secondary market (Fariña, 2019).

Clearing and settlement

After the trade has been executed, the bond is secured in a central securities depository before a clearing house steps in as an intermediary to confirm that the bond buyer has enough money to complete the transaction and that the seller owns the security in the central securities depository. Here, the risks are being reduced, and the clearing house takes a fee for this service. The transaction is sent for settlement after the clearing house has finished its job. Here is where the actual exchange of money and bonds takes place. The seller's bond is transferred to the buyer's account as the cash goes from the buyer to the seller. This is called delivery versus payment, which refers to the settlement of two obligations and can be defined as the settlement of the delivery of one security and the payment of cash (Kobayakawa et al., 2018).

Custody and asset servicing

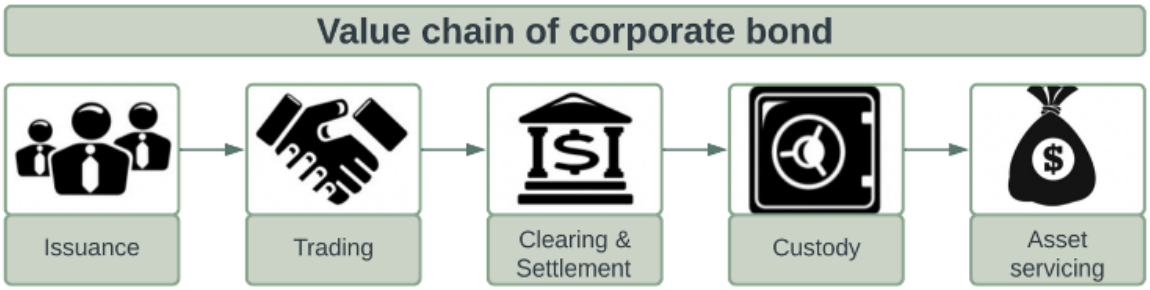

Figure 2 - Self-made illustration of the value chain for corporate bonds.

When the clearing and settlement of the security have been finalized, the bond is held by a custodian on behalf of the bond owner. The role of the custodian is to provide post-trade services for the asset owner. A custodian is an institution that acts as the guardian of its clients' securities and is responsible for the safekeeping of these securities (Deloitte, 2019). The custodian also keeps track of coupon payments for bonds and other cash transactions regarding the terms of the security. The value chain and process the bond goes through are illustrated in Figure 2.

2.5.4 Tokenized bonds

The traditional bond value chain is a complex structure with many different intermediaries that play a crucial role in the pre-trade and post-trade phases of the lifecycle of the bond. These intermediaries run on their own systems and depend on good routines for communicating across the systems. Bond markets and the issuance phase have not seen much innovation and procedure changes in the latest decades (Emerging Markets Group, 2005). However, emerging

technologies like tokenization, blockchain, and DLT could change the bond and security markets in the coming years. A market report from Roland Berger from 2022 suggests that the market for tokenized real-world assets, with real estate, debt (bonds), and funds being the top three most significant tokenized assets, will reach at least $10,9 trillion by 2030 and that the tokenized bond market could reach $2.8 trillion being the second most extensive tokenized asset (Roland Berger, 2023).

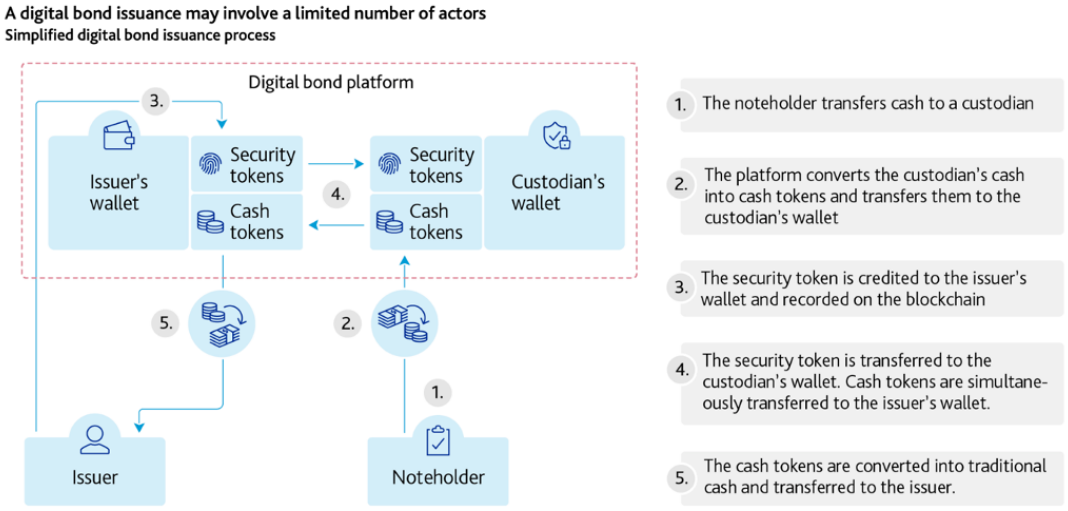

Figure 3 - Digital bond issuance. (Moody´s Investors Service, 2023)

The purpose of tokenizing bonds is to transform the traditional bond security into a representation on a blockchain as a token. By doing so, the asset holders and market makers have constant access to the assets' 24/7 information flow and frictionless updates on the changes to the bond's ownership, transactions, and conditions. One of the features that tokenization brings to the bond market is atomic settlement and removal of the clearing section of the value chain. By utilizing the functionality of smart contracts, processes that today are manual could be automated into the token itself. This will allow for reduced costs and increased automation of the value chain. Figure 3 provides an example of the potential simplicity of the exchange of the tokenized bond between the issuer and the investor. One can see that with a tokenized bond combined with a cash token, the process of trading and safekeeping the bond becomes simplified down to five small steps. The process would be even easier by not needing to convert the noteholder's cash into cash tokens by potentially having a DLT-based wholesale CBDC accessible. The figure is gathered from a paper published by Moody´s Investor Service, a bond credit rating company, on 6. July 2023. One can see that

tokenizing the bond will simplify the issuance process and create less friction (Moody´s Investors Service, 2023).

3. Methodology

The overall goal of this thesis is to explore what advantages the use of DLT-based wholesale CBDC and tokenization can have for bonds. Due to the lack of available reliable quantitative data and real-life use of CBDC and tokenization when issuing bonds, this thesis will be mainly based on a qualitative analysis, but also includes a quantitative case example based on assumed values. This thesis will be an exploratory study for the research design as it is flexible and adaptable to change as new information or data appears. "Exploratory research may commence with a broad focus, but this will become narrower as the research progresses" (Saunders et al., 2012, p. 171). The thesis aims to be unbiased and provide high validity and credibility.

3.1 Research Method

This thesis will be based on an explorative qualitative research approach. There are multiple ways of conducting explorative and qualitative research. Examples are searching existing literature, interviewing experts in the field, conducting in-depth individual interviews, or conducting focus group interviews (Saunders et al., 2012, p. 171). Given that CBDC and tokenization are relatively niche topics and not well known by the general public, we found that it would be most suitable for the thesis to use a "search of existing literature" and "in-depth interviews" approach. By interviewing experts on the subject, the credibility of the thesis will increase. Since qualitative research allows for changes in the structure and adaptation of the thesis as new information appears, it is essential to look critically at all the gathered data. Biases provided by either us or others can shape the thesis results. It is also necessary to analyze the quality and validity of the information. This applies in both the search for existing literature and throughout the interviews.

3.2 Data Collection

This thesis aims to analyze the collected data in-depth to answer the research question to the best extent. Our primary source for new information on the topic is through in-depth interviews with experts in the field. As some of the information gathered in the interviews might need to be factually correct, we use primary data from reports and secondary data from other sources

to control the information collected in the interviews. Most interview objects are associated with government organizations or private corporations within the field of CBDC or tokenization, and the views and opinions expressed by the interview objects do not necessarily reflect the views of their respective organization/corporation. The interview objects are instructed at the start of the interviews that the views discussed should be their personal views.

3.2.1 Literature review

"Reviewing the literature critically will provide the foundation on which your research is built" (Saunders et al., 2012, p. 73). When conducting research, it will be helpful to critically review existing literature on the topic before you start working on your research. There are two main approaches when studying literature. Firstly, a deductive approach where you use the literature to help you identify theories and ideas that you will test using data. The second approach is known as an inductive approach. Using this approach, the researcher will explore their data and develop theories that the researcher will subsequently relate to the literature in subsequent discussion (Saunders et al., 2012, p. 74). With an inductive approach, the research does not start with a predetermined theory and framework. Using this technique requires a more excellent knowledge of the topic beforehand than when using the deductive approach.

We´ve chosen a deductive approach in our thesis as we wanted greater knowledge about the topic before we started our analysis and data collection. We aim to review the most relevant research on the subject, and new theories or perspectives will appear as we review the existing literature. We will use the following checklist when choosing what research to include in our thesis.

- Have you ensured that the literature covered relates to your research question?
- Have you covered the most relevant and significant theories of recognized experts in the area?
- Have you covered the most relevant significant literature or at least a representative sample?
- Have you included up-to-date relevant literature?
- Have you referenced all the literature used in the format prescribed in the assessment criteria?

  (Saunders et al., 2012, p. 76).

By following this checklist, we can evaluate the included literature in an objective matter properly.

3.2.2 Interviews

There are three main ways of conducting interviews. These are Structured-, semi-structured- and lastly, unstructured interviews (Saunders et al., 2012, p. 374). Structured interviews are usually based on a standardized questionnaire with identical questions for each interview object. Each question is read to the interview object, and the interviewer records the response on a standardized schedule, usually with pre-recorded answers (Saunders et al., 2012, p. 374). Structured interviews are used to obtain quantifiable and are often called "quantitative research interviews."

In contrast, semi-structured and unstructured interviews are called "qualitative research interviews." During a semi-structured interview, the interviewer will usually have a list of themes and some key questions, and the pre-defined questions may vary from interview to interview. Using this interview technique may lead to some questions that might be omitted from different interviews depending on how the conversation goes. The order of the questions may also vary from interview to interview. The primary tool for this type of interview is typically an interview guide containing key questions and themes that will be explored during the interview. It is also common to have some prompts or comments to the question to help start the conversation (Saunders et al., 2012, p. 374).

Lastly, unstructured interviews are informal, and this interview technique is used to gain a deeper insight into an area you are interested in. There is no need for a prepared interview guide during this type of interview, and the interviewer and the interview object are allowed to talk freely on the topic without the constraint of a pre-defined interview guide (Saunders et al., 2012, p. 375).

For our interviews, we decided to opt for the semi-structured interview technique. The reason for this approach is that we want the freedom to have a conversation with our interview object without the constraints of a questionnaire and still have some key questions and probes to help lead the interview in the right direction. Our pre-defined questions are general and open-ended to avoid leading questions and bias when asking them. The interview guide is structured so the questions and probes suit interview objects from different sectors and varying knowledge.

The complete interview guide can be seen in Appendix B. All interviews will be conducted electronically via video call using Teams, Zoom, etc. The duration of each interview is roughly one hour. At the start of each interview, we will explain the overall objective of the thesis and some practical information about the interview. All the interviews will be recorded and quickly transcribed after the interview. When the transcription is finished, it will be sent to the interview object for validation, and they will be allowed to retract statements from the interview if they don't want them published in the thesis. The interview recordings will be deleted upon completion and grading of the thesis. Most of the interviews were in English, but some were in Norwegian (see Appendix C). As the Norwegian interviews had to be translated into English, some substance may be "lost in translation." It is also important to mention that none of the interview subjects (including us) were native English speakers and, therefore, had some difficulties expressing themselves in their desired manner.

To ensure a comprehensive understanding of the topic, we´ve approached a selection of experts based on their merits, published works, affiliation with relevant institutions, and their contributions to CBDC and tokenization. To establish contact with the interview objects, we used our network, contacting various institutions and being referred by other interview objects. The potential interview objects were contacted through either email or LinkedIn, depending on whether their email addresses were available. All interview objects were sent a standardized formal interview request, which can be viewed in Appendix A. Most of the replies we received to the interview request were favorable to participation. The ones who did not want to participate usually explained that it was due to a busy schedule, and some did not get approval from their respective organization. Only a few potential interview objects did not answer the request. The complete list of interview objects can be viewed in Appendix C. A study by Monique Hennink and Bonnie Kaiser at Rollins School of Public Health and the University of California San Diego reviewed empirical studies in qualitative research to assess how large sample sizes have to be for in-depth interviews. The study concluded that a sample size of 9-17 interview objects is sufficient (Hennink & Kaiser, 2021). In our thesis, we conducted a total of 10 interviews. We believe that our selection of experts is balanced across fields and backgrounds.

3.3 Bias, Reliability, and Validity

In this thesis, bias may stem from multiple sources. There is a possibility for both participant bias and researcher bias. Researcher bias is any factor that induces bias in the researcher's recording of response, i.e., when a researcher allows their subjective view to get in the way of interpreting participant responses (Saunders et al., 2012, p. 192). We acknowledge that preconceptions could influence how we conduct the research and conclude our findings. To avoid this, we looked at the topic from different angles. We did not ask leading questions during the interview process, allowing the participants to express their opinions without being affected by ours. The possibility of participant bias means that the participants provide incorrect answers to distort the result of the research (Saunders et al., 2012, p. 682). To mitigate this, we used existing literature to cross-check their statements.

Reliability in qualitative research refers to consistency and dependability in the research finding (Saunders et al., 2012, p. 192). To ensure reliability in our thesis, we used a semi-structured interview guide. By doing this, we collected the same general information from each interview and had consistency across the different interviews (see Appendix B). In addition to this, we also kept a clear overview of how we wanted our research process to be and followed our methodology throughout the thesis.

Validity is the consideration of accuracy and truthfulness in the findings in qualitative research. To ensure validity in our thesis, we fact-checked all findings used from the interviews to ensure they were factually correct. Lastly, we ensured that our findings were grounded in the data and provided quotes from the interviews to support our thesis.

3.4 Ethics

When conducting research, it is essential to consider ethics. Ethical concerns will appear during the research planning, collection and analysis of the data, and conduction of interviews. Research ethics refers to the standard of behavior that guides your conduct regarding the rights of the subject of your work (Saunders et al., 2012, p. 226). To comply with ethics during the interviews, we made sure to keep the interview objects informed about the aspects of the thesis. The formal interview request (see Appendix A**)** contains all necessary information about the thesis, and the interview objects rights to withdrawal, retraction, anonymity, and so on, in

addition to how we will process the collected data. This information is also repeated at the start of each interview, and we also ask for consent to record and transcribe the interview. Lastly, we always send the transcribed interview to the participant afterward for approval. All interview objects will gain access to the thesis upon completion. During the interviews, we collected and processed sensitive information and personal data. Therefore, we decided to report the thesis to SIKT (Norwegian Agency for Shared Services in Education and Research). The application to collect and process the information during interviews was approved.

3.5 Analyzing Qualitative Data

In qualitative research, meaning stems from words, not numbers, and since words have multiple meanings and unclear meanings, it is essential to clarify the meaning with great care (Saunders et al., 2012, p. 546). This leads to the quality of qualitative research to depend on the interaction between the data collection and the data analysis. For this reason, we made sure to familiarize ourselves with the recording of the interviews and the transcribed interviews. This helps us gain a general sense of the information and its underlying meaning. After familiarizing ourselves with the data, we started categorizing our data under different categories such as themes, ideas, concepts, etc. The categorization will make analyzing the collected information from the interviews easier.

After categorizing the transcribed interviews, the next step in the analysis is identifying themes in the transcriptions. The themes are patterns or issues that recur in the data and are essential in determining the consensus on the topic. The last step of the analysis is interpreting and reporting the data. Interpreting data involves explaining the themes, how they can answer the research question, and how they relate to existing literature. When reporting the data, presenting the findings clearly and systematically is essential. This is done by including quotations from the interview objects, letting them speak throughout the thesis, and discussing how the findings relate to the research question and the existing literature. The analysis will be presented in chapters 4-6, starting with an analysis of retail CBDC.

4. Retail Central Bank Digital Currency

Central banks representing more than 90% of the world's GDP are exploring the possibilities for developing CBDCs. Most economies focus on retail CBDC (rCBDC), not wholesale CBDC (wCBDC). The organization "CBDC tracker" offers the status of worldwide CBDC projects and divides the status into five categories: Cancelled, Research, Proof of Concept, Pilot, and Launched. The Central Bank of Norway is currently in the phase of the proof of concept (CBDC Tracker, 2023).

With a retail CBDC, central banks can provide the population with a safe and trusted alternative to cash in a cash-declining society issued by the central bank itself. rCBDC would offer the same functions as cash but with additional features that set it apart from cash, bank deposits, and credit cards. In addition, an rCBDC would fill the gap between electronic, central bank-issued money and being universally accessible. There are varying opinions on when or if rCBDC should be implemented in different nations' economies.

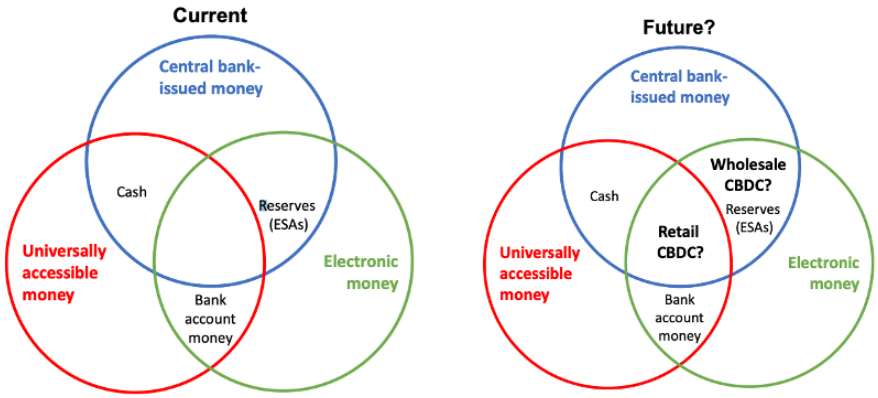

Figure 4 – The current and future economy by introducing CBDC (Richards et al., 2020)

4.1 Benefits and Use Cases

Several benefits and potential use cases have driven the interest in developing a general-purpose retail CBDC. One common benefit is enabling access to central bank-issued money for digital transactions as cash usage declines. When we asked Peder Østbye, Director of Analysis at the Norwegian Central Bank, about the motivation for developing an rCBDC, he replied, "In Norway, we saw a great decline in cash usage, and cash has been less relevant and

usable, and therefore it was natural for us to explore a retail CBDC (…)". An rCBDC will be the only form of private money except cash backed and issued by the central bank. Money issued by a central bank is a riskless form of currency since there is no risk of the central bank going bankrupt. However**,** this applies to well-run central banks, for economies experiencing hyperinflation and corruption, central bank issued money is not considered riskless. Money kept in a bank account is a claim on the bank and is therefore exposed to credit risk as there is a risk of the bank going bankrupt (EY Norge, 2020). The bank's risk of going bankrupt is low, and in Norway, money up to 2,000,000 NOK is secured in a bank deposit guarantee[7], but there is a specific credit risk. The credit risk becomes more apparent with E-money, i.e., if PayPal goes bankrupt, the deposits are lost. In contrast to central bank issued money, cryptocurrencies are, in theory, exposed to infinite credit risk (EY Norge, 2020).

Østbye added that there was another motivation for developing an rCBDC; "(…) The infrastructure for banking services became more concentrated. More international players have been involved, and this has led to less control for the Norwegian authorities over the banking system and less regulation. (…)". With instant settlement, rCBDC would be an alternative to companies such as Vipps, PayPal, Apple Pay, and others. The instant cross-border settlement across different currencies would set rCBDC apart from the existing solutions. The Project Icebreaker collaboration between the central banks of Norway, Sweden, and Israel has proven successful. During the testing of this project, the central banks successfully transferred funds between the three countries using different currencies on different ledgers (Bank of International Settlement, 2023).

Only time will tell if retail CBDC will become the preferred means of making retail payments or if existing private companies will continue to offer the best solution for consumers. Nadia Pocher, a post-doctoral researcher from SnT, believed that the main selling point for rCBDC was cross-border payments; "(…) For cross-border I think it could potentially make things very different, for instance, if you travel elsewhere you don't have to change your money (…)". In addition to faster and cheaper cross-border payments, rCBDC could offer fewer fees and eliminate non-favorable exchange rates when traveling.

[7] The bank deposit guarantee of Norway covers up to 2,000,000 NOK through a scheme named "Bankenes Sikringsfond". The fund is financed through contributions by financial institutions to low-risk and high-liquidity bonds. The value of the fund is approximately 20 billion NOK (Bankenes Sikringsfond, 2023).

4.1.1 Programmability

Retail CBDC can be offered as either a traditional bank account for basic transactions or with features such as programmability. With programmable money, the payment processor can enable payment conditions in addition to sending/receiving money (De Nederlandsche Bank, 2020). One use case could be subsidies from the government paid out to people in need of healthcare. The government can restrict the subsidies so that the funds can only be used for healthcare purposes. The programmability of rCBDC is not only limited to payments. It can also be used for purposes such as calculating exact interest. As Lasse Meholm, head consultant on the rCBDC project in the Central Bank of Norway, noted in our interview.

> *One of the things we did in Norges Bank is that we calculated interest on CBDC. We used the ERC20 token, which is a smart contract, and reprogrammed it in a way that made it able to calculate interest on itself. It did this by finding out when the last time it received funds was, and after that, we took the interest rate and divided it by seconds in the year. In the end, we calculated the exact interest that you should be paid down to the second and 16 decimal precisions. Throughout the process, we found that the interest you gain in banks is most likely incorrect. (…) On average, we used 128 milliseconds per transaction. (…)*
>
> - *Lasse Meholm, Norges Bank*

Using the process described by Meholm, the bank or the central bank no longer calculates the interest. It is now the money that calculates interest on itself. In theory, this would be a fully automated process, and it being on the blockchain, it would also be a trustless and immutable system. Lasse Meholm also mentioned that the Norwegian Central Bank has been working on using a programable rCBDC to avoid tax evasion and money laundering.

> *(…) We also checked if it was possible to implement anti money laundering, and we did this by contacting The Norwegian Digitalization Agency (Digdir), and with them, you can receive a certificate for your social security number. This certificate can be added to your CBDC wallet. We then reprogrammed the money so that the funds could not be owned by someone without a valid certificate. We have created a possible solution to tax evasion and money laundering by reprogramming the money. This is something no one has ever done before.*

- *Lasse Meholm, Norges Bank*

There is a discussion in the world of CBDC on what level of anonymity should be offered with rCBDC while still being compliant with anti-money laundering (AML). There are suggestions for different designs for rCBDC regarding privacy, ranging from complete privacy to minimum privacy and controlled anonymity. The ECB has published a report concluding that it is possible to balance privacy for low-value transactions and AML checks on high-value transactions (European Central Bank, 2019). Using the solution explained by Lasse Meholm, it would be possible to eliminate much of the risk regarding AML and tax evasion. In addition, if a rCBDC were placed on a blockchain, it would be possible to see each transaction as the public key will leave a signature on the blockchain. This would make it easier for authorities to trace the origin of the funds, and therefore, it would be hard to launder money using rCBDC.

Although the mentioned programmability features may be less appealing and exciting for consumers, the programmability of rCBDC can be used in everyday situations. One possible application can be when buying a car; the payment can be programmed not to be transferred until proof of ownership is transferred from the seller to the buyer. This eliminates some risk and uncertainty during the process.

4.2 Challenges

4.2.1 Bank runs

Although there are multiple benefits and use cases for a retail CBDC, it will come with its challenges. One of the most significant concerns is the implications of financial stability risks. A rCBDC could lead to economic instability and bank runs. One of our interview objects, Christoph Gschnaidtner, a researcher from the Technical University of Munich, researched whether a rCBDC might foster bank runs.

> *(...) So, what I'm looking at are the negative aspects of a CBDC and how it can influence the financial markets in particular, and corporate banks. What I'm exactly doing in that project is that we have an experiment, and we have our participants exposed to a bank run situation and have different scenarios. In one scenario, the participants have the possibility to withdraw their money in the form of CBDC. What we actually find in that project is quite interesting, particularly participants exposed*

> *to this CBDC scenario are very, very likely to actually have a bank run. Particularly if they consider the situation as very risky. (…)*
>
> - *Christoph Gschnaidtner, T*echnische Universität München

Christoph's research shows that unrestricted access in situations with uncertainty can potentially lead to bank runs. A potential bank run will lead to fewer deposits in commercial banks, creating implications for bank funding and making banks rely more on wholesale funding, which is more expensive. A large bank run can lead to financial instability and potentially a financial crisis. Bank of International Settlement (BIS) has reported on how rCBDC can impact financial stability. The report concludes that bank runs are possible, but the impact depends on multiple factors. Factors such as limitations on rCBDC holdings, non-interest bearing rCBDC, and design features of the rCBDC can reduce the risk of financial instability (Bank of International Settlements, 2021).

4.2.2 Trust and understanding

Trust and understanding from the population regarding CBDC are essential for a successful retail CBDC project. Many have the misconception that CBDC and blockchain technology are the same as cryptocurrencies and, therefore, see them as risky and speculative assets. Scandals like the FTX collapse could lead to people not trusting the technology. This is something multiple of our interview subjects raised concerns about.

> *People are usually scared of new things coming, but to me, the selling point of a DLT is that it is a trustless system. I feel that there is a snowballing effect with the FTX scandal and beliefs that have been distributed so far that no one dares to go against them. This is not going to help adoption. So maybe it is a question of time, or maybe it is because there is not a DLT lobby. Like you got different initiatives, but there is no lobby. Maybe we need a lobby, I'm not sure. It is a bummer that there are so much wrong beliefs, and this is not enabling a full-use DLT, but when you think of it wasn't the same when they invented the car? (…)*
>
> *- Alexandra Thomé, Deutche Bundesbank*

This issue may disappear as people get used to the idea of CBDC, as the launch is a couple of years away. It may not be the right time for people to understand it from a retail perspective,

and in 5-10 years, this type of technology will be more normalized. Østbye believes that it may not be necessary for everybody to understand how CBDC works to use it.

> *(…) I believe that most people do not think about how these things work. They just want it to be fast and cheap. So, in the future, most people won't really know what CBDC is and what bank money is unless there is a crisis. You don´t really think about which bank you have your money in unless some of the banks go bankrupt cause then you want to have your money in a secure bank. (…)*
>
> - *Peder Østbye, Norges Bank*

As long as things work and there are no crises, people will choose to use what is most efficient for them and will not care if they use rCBDC or money from their bank account. For those who prefer cash, rCBDC will provide cash-like features such as anonymity and additional features in certain situations. If one disregards countries such as Norway, where the trust in authorities is high, distrust in the government is also a threat to CBDC. Katharina Gehra, CEO and Co-founder at Immutable Insight, raised concerns on this issue.

> *(…) On your side, under the assumption you live in Norway, and you have a general trust in the public and a general trust in the Norwegian institutions. But consider living in St. Petersburg or living in Iran. That is the issue with central bank digital currencies. They are political instruments. (…) If you look at the S&P rating for country bonds. And if you think that such a rating system will be applied to all corporate bonds, all country bonds, there would be a fairly transparent and fairly neutral rating system. But inherently, no rating systems are, but it is a good approximation. More than 60% of state-issued bonds, according to S&P, have no investment grade globally. That means that their currencies have no investment grade, which means that more than half of the population of this planet lives with currencies that are not trustworthy by a rating agency. (…)*
>
> *- Katharina Gehra, Immutable Insight*

If you can't trust the government, it will be hard to trust a CBDC issued by the government, and with a currency that is not investment grade, it will be even more complex. According to Trading Economics, 88 out of 155 countries have government bonds rated BB+ or lower by S&P, meaning the bond is not investment grade (Trading Economics, Unknown Date).

4.3 Implementing Retail Central Bank Digital Currency

Launching retail CBDC in regions such as Norway and the EU will take a while. There are a lot of technical, legal, and political aspects that must be figured out before a possible launch. As of November 2023, only three regions have officially launched their own rCBDC: Nigeria, Bahamas, and Jamaica (CBDC Tracker, 2023).Typical for the three rCBDC projects is that their launch could have been more successful; they all have experienced low usage relative to the population. In Jamaica, only 0,01% of electronic retail transactions use rCBDC (Muir, 2023). The overall motivation for launching rCBDC in Jamaica was to increase financial inclusion, and time will tell whether it will have an effect in the future. The launch of rCBDC in Nigeria, the Bahamas, and Jamaica shows that it is essential for nations to thoroughly research, test, and educate the population on rCBDC before launching the finished product.

The Central Bank of Norway has since 2016 explored CBDC and is currently working on phase 5 of the project. The previous phases have looked at important aspects of CBDC that need to be explored before implementation. In the first phase, the central bank discovered different conditions that had to be emphasized in an assessment if CBDC should be implemented. The second phase explored possible purposes for CBDC and alternative designs to achieve these purposes. In the third phase, they discussed CBDC's characteristics, possible technical solutions, and the consequences of implementing CBDC. The fourth phase discovered necessary legal and regulatory changes that had to be done to implement CBDC (Norges Bank, 2023).

When we asked Lasse Meholm how he imagined implementing retail CBDC would look, he said he believed it would take a long time. By the end of 2025, the Central Bank of Norway will finish phase 5, where they will write a report on whether they recommend Norway to pursue rCBDC. “This report will be sent to the Norwegian Parliament, where they will probably spend a year or two to decide whether they want to pursue it or not.” If the Parliament wants to proceed with rCBDC, the Central Bank of Norway must develop the necessary systems to facilitate rCBDC. The banks must change their systems, and retailers must also modify their systems. This is a long and time-consuming process, and we will probably not see the launch of a rCBDC in Norway for quite some time.

5. DLT-based Wholesale CBDC

In contrast to retail CBDC, wholesale CBDC is generally not a focus area for most central banks exploring CBDC. Only the central banks of France and Switzerland have launched a pilot wholesale CBDC in Europe, but they are yet to launch a fully functional wholesale CBDC. Wholesale CBDC refers to the settlement of interbank transfers related to wholesale transactions in central bank reserves. One common misconception is that wCBDC is something new, as Johannes Sedlmeir, a researcher from SnT, brought up in our interview; "I mean, banks do already have access to this digital euro, at least in Europe. (…)" Central bank reserves have been available in digital form for a long time. Settlements made through the Target system are a form of wCBDC (Panetta, 2022). This thesis explores a modernized version of wholesale CBDC based on distributed ledger technology. This is not the same as the current digital central bank reserves for interbank settlement.

5.1 Settlement

A potential key benefit of a DLT-based wholesale CBDC is faster and more efficient settlement for wholesale transactions. Currently, interbank settlements are made using RTGS systems and typically follow the T+2 model, where settlement is to be completed within two business days after the trading day. The current model introduces counterparty risk for a potential default during the settlement process and creates a liquidity demand to fund unsettled transactions.

A DLT-based wholesale CBDC can achieve an atomic settlement, meaning delivery versus payment happens instantly, reaching T+0. This can reduce the counterparty risk and liquidity demand, making the settlement process more efficient (Panetta, 2022). Combining the features provided with a DLT-based wholesale CBDC makes the atomic settlement possible. This includes instant payment, programmability, and value chain automation. Jon Ramvi, a Web3 consultant for the public sector in Norway, mentioned that this was one of the main use-case opportunities and incentives for wCBDC. "The programmable nature of CBDCs, especially when combined with smart contracts, can open up for innovative financial products and services, making it possible to automate complex financial processes. It will be easier to make atomic operations in complex value chains with multiple stakeholders." Using smart contracts alongside wCBDC can introduce efficiency and monetary savings when trading securities. A

more in-depth discussion on this topic can be found in Chapter 8. In addition to settling financial assets, wCBDC can significantly impact cross-border settlements across different currencies.

5.1.1 Cross-border payments

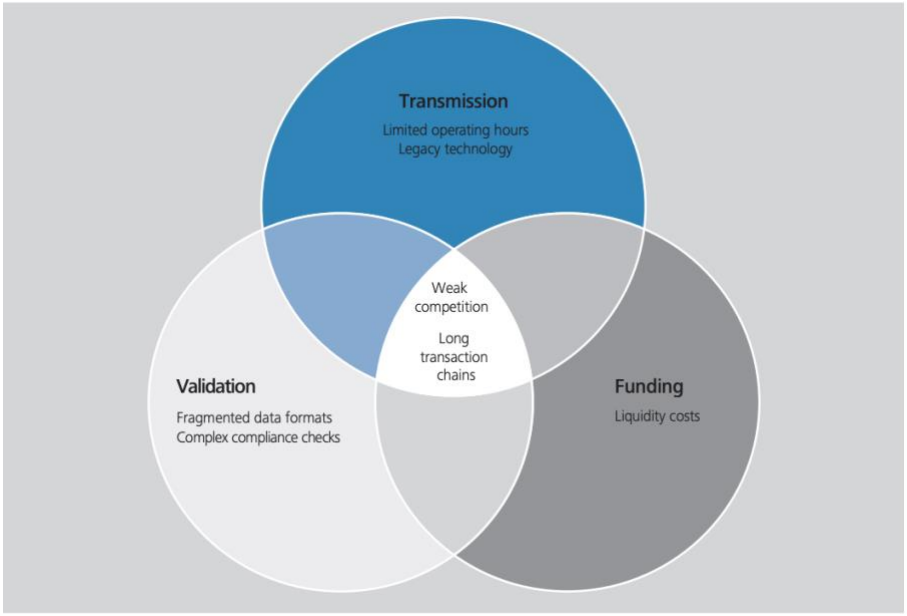

Figure 5 – Frictions in cross-border payments (Deutsche Bundesbank, 2022). Based on Financial Stability Board (2020b).

The Group of Twenty (G20) countries have set 2027 as their target date for improving cross-border payments to an acceptable level (Deutsche Bundesbank, 2022). Figure 5 displays existing frictions in cross-border payments. Long transaction chains and weak competition for cross-border payments are common for funding, validation, and transmission. The necessary improvements to eliminate frictions in the current cross-border payments can be made by introducing wholesale CBDC to G20 countries' economies. The G20 countries have set multiple targets to reach within 2027, which can all be achieved with wCBDC. Firstly, by the end of 2027, 75 % of all cross-border transactions should be settled within 1 hour, and the remaining 25% should be settled within the day. The instant settlement with wCBDC makes this possible. Secondly, by the end of 2027, all financial institutions should have at least one option for cross-border payments. A DLT-based wholesale CBDC would be a viable solution for this. Thirdly, in terms of transparency, by 2027, payment service providers should supply both the payer and payee with a minimum standard of information regarding transaction costs, fees, time to deliver the funds, and tracking of payment status (Deutsche Bundesbank, 2022).Depending on the design of each wCBDC, the degree of transparency may differ.

However, all targets regarding transparency are technically possible to fulfill. Although it is unlikely that there will be a widely available wCBDC by 2027, the G20 countries show an interest and need for the technology and features wCBDC delivers.

5.2 Interoperability

Even though the technical capabilities have been demonstrated, real-time settlement with wholesale CBDC introduces integration challenges with legacy systems. During our interview with Alexander Rieger, assistant professor at the University of Arkansas, troubles regarding interoperability with legacy systems were discussed.

> *Interoperability is always an issue. (…) But most often, it will be about existing legacy systems. So, the question is less about whether we are able to connect Hyperledger Besu to Chrome (two different DLTs), but rather are we able to connect Hyperledger Besu to some arcane API that none of the young developers that are now on our CBDC project have ever seen. If you can´t connect your project to legacy systems, you have a standalone system basically, then your project will tank. So, interoperability is important. (…)*
>
> *- Alexander Rieger, University of Arkansas*

For a wCBDC to be successful and make processes more efficient, the DLT must work with existing legacy systems. The French Central Bank, Banque de France, is one of the central banks currently working on a DLT-based CBDC. Banque de France has brought up the interoperability issue as an essential factor to consider when working on a wCBDC design. It has stated that two main hurdles must be avoided. Firstly, post-launch, the need for "tinkering" with interoperability solutions should be avoided; this could reproduce the current inefficiencies of existing RTGS systems, which are not natively interoperable. Secondly, a launch lacking collaboration with other central banks could cause a forced international standard that others would have no choice but to follow (Beau, 2023). As not all central banks will launch their wCBDC simultaneously, or at all, interoperability with legacy systems is essential. Compatibility between different nations' CBDCs is necessary to ensure efficiency gains. The design of a wCBDC needs to be as future-proof as possible and adapt to a rapidly changing environment.

5.2.1 Different approches to interoperability

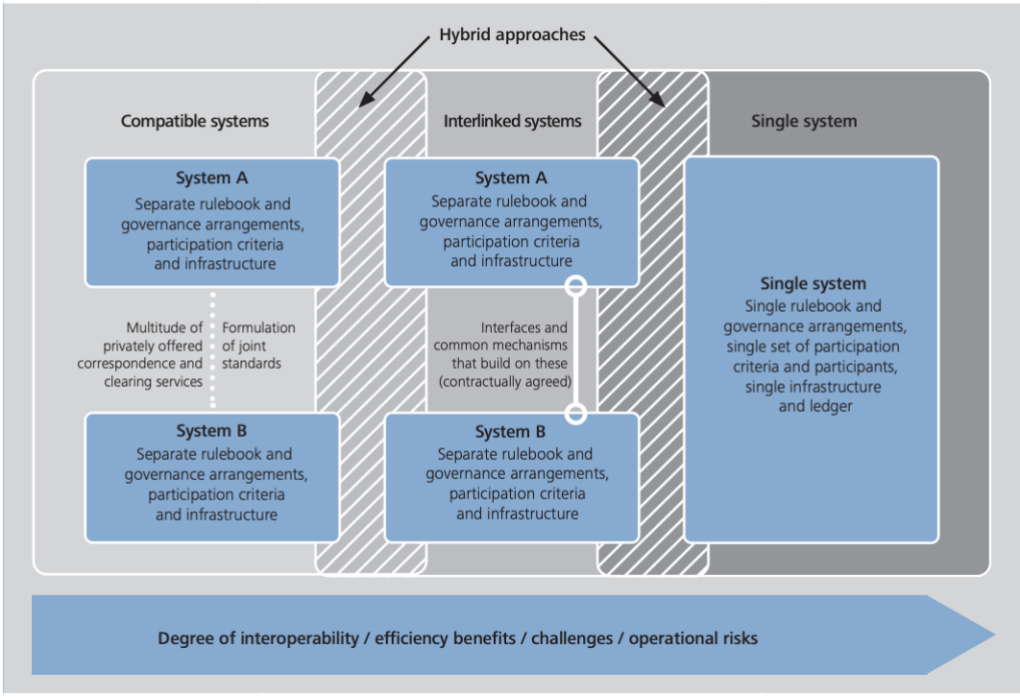

Figure 6 - Interoperability approaches for CBDC systems. (Deutsche Bundesbank, 2022) Based on Auer et al. (2021).

Deutsche Bundesbank published in 2022 a report on the interoperability of cross-border payments with CBDC. Figure 6 displays different interoperability approaches to consider when launching a wholesale CBDC. The three design options are compatible, interlinked, and a single system. Compatible systems operate independently but comply with common technical standards and rules to reduce friction from legacy systems. There are, however, some obstacles to overcome before achieving true compatibility; even with common standards, differences in interpretation and application may still apply. Compatible systems still rely on correspondent banking or other mechanics for cross-system payments (Deutsche Bundesbank, 2022). Interlinked systems allow direct payment between participants in different CBDC systems without joining the other system. Interlinked systems require a common technical interface and standards to exchange information and cross-system payments but also require more coordination than compatible systems. Each central bank still controls its issuance and participation in its subsystem. Project Jura by BIS successfully tested a cross-border purchase of DLT-based security against a wCBDC in Euro followed by an exchange in Swiss Franc wCBDC using an interlinked system (Deutsche Bundesbank, 2022). Lastly, a single system is a platform with a single rulebook, technical system, and participation criteria. An international organization would operate the system and offer greater functionality and efficiency than

interlinked- and compatible systems due to the high integration (Deutsche Bundesbank, 2022). This solution is objectively the best and most efficient, but due to increased initial investment and coordination between multiple nations, it is unlikely that this system will be implemented. In addition to these three solutions, there would also be a possibility of a hybrid solution that could have features from all three systems.

5.3 Competing Alternatives

While some central banks are exploring DLT-based wholesale CBDC with features such as atomic settlement, efficient cross-border payment, and programmability, there are private sector initiatives that can offer the same functionalities without the need for a central bank-issued digital currency. Christoph Gschnaidtner stated, “There are plenty of stablecoins out there that could actually perform what digital currencies could do. (…)”. Privately issued stablecoins have emerged as a seemingly viable alternative to CBDC despite possible threats regarding their risks and regulatory aspects.

5.3.1 Stablecoins

The purpose of stablecoins is to offer a form of cryptocurrency where the coin's value is pegged towards a real-world asset. This can be assets such as different currencies, commodities, or other financial instruments. This contrasts traditional cryptocurrencies, whose value is not backed by real-world assets other than their technology. As multiple stablecoins are available today, many of the features wholesale CBDC offers are available, while wCBDC might be years away. Nadia Pocher explained in our interview that because stablecoins do not have to go through the same political, regulatory, and research steps as CBDC, they will take less time to launch. Although stablecoins offer many of the same features as a wCBDC, they do not come without risk.

> *The problem with stablecoins is that it´s highly inefficient. If you want to stay on par, you need excess collateral backing for these coins. Therefore, you have the risk of devaluation of the underlying asset. Legal frameworks such as MiCA can reduce some of the risks, but the risks are still there.*
>
> *- Alexandra Thomé, Deutche Bundesbank*

While stablecoins are designed to minimize risk and volatility, they cannot replicate the riskless nature of wCBDC. A stablecoin is constantly exposed to some risk, which can be counterparty, underlying, or credit risk. Following the introduction of the MiCA framework, the risks related to stablecoins are expected to be reduced. Measures such as banning algorithmic stablecoins and only allowing real-world asset-backed stablecoins are expected to reduce the risks (Legal Nodes Team, 2023). Although risks have been reduced, stablecoins are not fully riskless.

> *(…) So, I think there are definitely some very good solutions out there who basically could take the role. But regarding the state of current stablecoins, I see that people are just not going to trust them because of its counterparty risk, and that's something you don't want to have. Central banks, in contrast, do not have counterparty risk because they can't default.*
>
> - *Christoph Gschnaidtner, T*echnische Universität München

Although risks with stablecoins can be reduced through the implementation of MiCA, they are not fully riskless compared to wCBDC.

5.3.2 Tokenized deposits

Tokenized bank deposits are an alternative to both stablecoins and wholesale CBDC. Tokenized deposits refer to digitizing deposits and transforming them into tokens on a blockchain, which directly represent the value of the underlying deposits (Dubey, 2023). Stablecoins and tokenized deposits are similar in that they both can be pegged 1:1 against underlying deposits. Still, stablecoins are pegged against external deposits, while tokenized deposits are pegged against only the owner's deposits. Wholesale CBDC, stablecoins, and tokenized deposits can facilitate instant settlement, cross-border payments, and programmability. J.P. Morgan is one of the commercial banks that has experimented with tokenized deposits using their JPM Coin. As of October 2023, J.P. Morgan claims that JPM Coin handles 1 billion USD of daily wholesale transactions (Ghosh, 2023).

> *J.P. Morgan has introduced JPM Coin, and all these large American banks work with tokenized bank deposits. CBDC is also tokenized money with the technology we´ve envisioned. All forms of private tokenized money come with a credit risk, if the issuer goes bankrupt the money is lost. The deposit guarantee of 2 million NOK is not really*

> *a large sum, wholesale investors deal with amounts much greater than this. If the Central Bank of Norway launches its own CBDC, there is zero credit risk. There is a great difference between privately issued money and publicly issued money.*
>
> *- Lasse Meholm, Norges Bank*

While tokenized deposits introduce more risk than a wCBDC, they are still less risky than stablecoins since they are unaffected by the same underlying risk. The chance of a large bank such as J.P. Morgan going bankrupt is low, but it is possible, for example, during a financial crisis. In 2008, multiple US banks went under, and through the bankruptcy of the large bank Washington Mutual, assets worth 307 billion USD were lost. More recently, in 2023, Silicon Valley Bank went bankrupt (Tani, 2023).

5.3.3 Target2-Securities

The Target2-securities system (T2S) offers many of the same benefits and features as a potential DLT-based wholesale CBDC. This is by providing an instant settlement of securities, reducing the cost of cross-border securities settlement, and pooling collateral. All these features reduce settlement risk and increase financial stability by using central bank money for transactions on the T2S system. Each transaction using T2S is completed by matching instructions from central securities depositories on a delivery versus payment basis, and the money and securities change hands simultaneously, achieving an atomic settlement (European Central Bank, 2023).The T2S settlement system is not available for all markets. Currently, 23 member countries can take advantage of the settlement system. There are several demands for new participants, including but not limited to the following: the applicant must be established in the European Economic Area, have a cash account in Target2, and comply with other conditions and legal requirements. Ultimately, the Governing Council of the European Central Bank decides whether they want to grant access to the T2S (The European Union, 2019).

While T2S proves that some of the unique selling points of a DLT-based wholesale CBDC are possible without blockchain technology, there are, however, some important differences between the two. The atomic settlement of T2S is only available to the participating countries, and as not all countries can become a member, it is less inclusive than wCBDC. The T2S does not allow for instant settlement of securities across different markets, for example, when trading securities in the USA, with non-participating countries, or with currencies different from Euro/DKK. This limits the possible use of T2S compared to settling securities with

wCBDC and tokenization. DLT-based wholesale CBDC allows for programmability for settlements with tokenized bonds, while settlement with T2S completes transactions by information matching. The two solutions settlements share some similarities, but programmability offers additional features to information matching.

6. Bonds

6.1 Current Bonds

6.1.1 Pre-issuance phase

In current bond markets, it is essential to distinguish between the pre-issuance and post-trade phases of the lifecycle of bonds. In the pre-issuance phase, the foundation is created for the bond issuance. This is where decisions on specific terms like maturity, date, interest rates, and rating of the corporation by an agency are made. In this phase, the price will be set through an auction, book-building process, or over-the-counter (OTC)[8] agreements, and the agreement between the issuer and investor is established (International Finance, 2021). The workload and costs of analyzing the issuer depend on the kind of bond and its risk. If an investor wants to invest in a covered bond, often with a AAA rating, the workload here is less than if you invest in a high-yield bond. Ole Einar Stokstad, currently working at Norselab as a senior portfolio manager in high-yield, has 17 years of experience within DNB Markets and has been working recently on the buy side of bonds, pointed out.

> *(….) If you do an 8-billion transaction for a covered bond company, you don't require any in-depth analysis. Everyone knows what it is. Everyone knows what the risk is. You don't need to think about much other than whether it fits into their portfolio with duration and currency. So, it's a small amount of work in relation to the volume. So, if you're going to do a 500 million transaction in high yield, it requires more work, and the investor must understand the risks and the special terms. Things can break, which means that you have to keep an eye on them, they have to be analyzed, and you have to understand the underlying. You have to understand the capital structure. There are a lot of people who need to understand what's going on before you take the risk of lending money to that company. And what terms to accept, and there are negotiations back and forth. You can say, "I'd like to buy it; I can take 30 million in that bond loan if you change the terms." And then, if enough investors say the same thing, you might*

[8] OTC: Over the Counter is the process of trading securities via a broker-dealer network instead of on a centralized exchange like New York Stock Exchange (Murphy, 2023).

> *get a change. If not, it will be what it is, and then you have to choose to "Take it or Leave it." So it's a completely different type of work per deal.*
>
> *- Ole Einar Stokstad, Norselab*

Stokstad means that in this segment of the bond's lifecycle, the work with the bond analysis needs to be done properly to highlight the risks considered with potentially investing or not. The workload is especially high for high-risk non-investment grade bonds rather than for investment-graded covered or government bonds. If you were to issue a bond without doing the work with high quality, the investors might not consider investing in the bond, or the issuer may not comply with the terms. Whether you issue a digital tokenized or traditional bond, this work needs to be done.

6.1.2 Post-trade phase

When the bond is issued and the terms are settled, one enters the post-trade phase. In this stage, the actual issuance of the debt security is executed. This issuance is done through central security depositories and then is delivered to the investor's custodian, often in the form of a bank. The delivery of the bond security to the investor's custody is done in exchange for money. As discussed in theory, the post-trade phase of bonds consists of a complex structure of intermediaries interacting with each other to finalize the trade and safekeep the bond security until maturity. Inefficiencies can arise due to communication delays, manual processing, or the need for information reconciliation between different parties (International Finance, 2021). The more intermediaries there are, the more likely inefficiencies will occur. In the interview with Lasse Meholm, he discussed securities trading and how they are cleared and settled in basic terms.

> *(...) The bonds must have an account operator in Norway for the shares. This is managed by the Norwegian Central Securities Depository or Euronext. Then, they must ensure that the shares are listed on the stock exchange. This is exactly the same principle for bonds. But bonds often have a syndication process upfront. And then you have someone who has issued a bond and someone who doesn't have the bond and wants to buy it. And when the trade is matched, an account manager comes into the picture. An account manager is usually the bank that has an account manager who ensures that the securities account is updated.*

> *Then, there is the settlement, which a bank also arranges. If one is DNB and the other Nordea, the payment goes via Norges Bank's settlement system, where the infrastructure is called NICS. This is the mechanism that ensures settlement between banks. At Norges Bank, DNB, and Nordea each have a deposit account called the central bank reserve. This is money that the banks have deposited in the central bank so that settlement can be carried out. But what actually happens is that bonds change hands, and then money changes hands. (...)*
>
> - *Lasse Meholm, Norges Bank*

Even though the process may be complex, and the intermediaries have their agenda, as Meholm points out, it all can be broken down to that in the trade and settlement of bonds, the bond security needs to change hands, and the money needs to change hands. After the bonds have changed hands, some required procedures must also be encountered, such as custody, asset servicing, and changing terms if necessary.

6.2 Benefits and Challenges within Tokenization of Bonds

6.2.1 Settlement

One of the main benefits of using tokenization and DLT technologies in the bond and securities markets is that they reduce the settlement time from T+2 to T+0 or an atomic settlement. This is the time it takes for the bond and money to change hands, as Meholm mentioned. The current T+2 settlement time has a downside when it brings a specific settlement or counterparty risk. The risk is often considered to be most substantial in connection with the default of one of the parties of a transaction. Default risk is the risk of one of the parties failing to deliver on an entered contract, and in financial markets, it is in connection with one part of the transaction going bankrupt before the settlement is completed (Kagan, 2022). Solving this using blockchain technologies requires the security and the cash payment to be tokenized or DLT-compatible. The reduction in settlement time will reduce or remove counterparty risks. As Meholm mentioned, if you break it down, it is just about the exchange of bonds versus a payment. Blockchain technologies can improve this settlement process as Meholm continues.

> *(...) This is something blockchain technology can do in an atomic transaction. This ensures that both things happen at the same time and removes counterparty risk, which*

> *is an important part of the financial markets. (…) As there is really very little going on in these transactions, it is possible to remove these boxes, and the buyer and issuer can have their own wallet. In these wallets, there are tokens that represent the ownership of the bonds that are there. These tokens should change hands, and if the money is tokenized, for example, using CBDC, you can utilize an atomic transaction that exchanges the bonds with money. And here, the issuer can see, at any time, who owns my bonds right now every single millisecond around the clock. But you always need someone to validate the transaction and make sure that the issuer actually owns the bond and that the buyer actually owns the money.*
>
> *- Lasse Meholm, Norges Bank*

Conversely, the current settlement system with T2 and a settlement time of T+2 days seems to work fine, and the counterparty risk is well managed. According to Alexander Rieger, reducing the settlement time from T+2 down to seconds is not only because you want to reduce the counterparty risk but also about improving the efficiencies in the process. "To me, at least, from an outsider's perspective, this is really about efficient processing, so really cutting down the settlement time from two to three days to ideally seconds and reducing many of the other inefficiencies and costs that accrue over these two days."

6.2.2 Costs and efficiency

The efficiency and cost aspects are significant incentives for introducing the technology to the bond markets. One of the main reasons for banks and other intermediaries to introduce the tokenization of bonds into their systems is the potential to reduce costs. Katharina Gehra said in our interview that the bond market has a market structure similar to an oligopoly. An oligopoly market is a market dominated by a few large firms (Hennerich, 2023), and according to a journal written by Valverde et al. 2021 on the non-pricing drivers of underwriters' market shares in corporate bond markets, the underwriting business has been dominated by larger investment banks for a very long time. Smaller commercial banks have tried to gain traction in the market but have remained in a low volume (Valverde et al., 2021). When Katharina Gehra was asked how she sees tokenization influencing the issuance of bonds and how they are traded and managed in primary and secondary markets, she replied.

> *I do see tremendous opportunities and potential for both, making it faster and making it way more efficient and less expensive. And that is anywhere from buying it in the*

> *primary issuance to holding it, selling it, or reconsolidating it in your systems once it's even gone again. If you think about it, how certain services have become fully digitized and are so different from what they were used to be. A bond issuance is still very much the same. It has not changed much the recent years. The market structure is an oligopoly, and no one is going to take something away from somebody else. And a lot of asset managers have made a lot of money during the time of quantity easing, so cost was not really an issue of the banks. Now that markets have become more distressed, also particularly now the last year in 2022 with minus double-digit returns in stocks and bonds, there are now a lot of asset managers that need to manage costs again. And if you think about it, if you transfer privately, so you don't sell, but you transfer shares from one share account to another, it may take up to four weeks. While in the SEPA payment, you can have instant payments within less than a minute. So, within the payment architecture, the payment competition has been so intense and so strong, so almost all indicators from a client perspective have improved. It is more effective; it is faster. While on the asset transfer side, none of these things, or hardly any of these things, have happened.*
>
> *- Katharina Gehra, Immutable Insight*

Gehra emphasizes that many asset managers have earned significant money on bond issuances. Because of the expansion in the volume of bond markets, there have not been great incentives to improve the cost management and efficiency of the processes until the worst year in the history of bonds, 2022, when they dropped 13% in prices (Rosen, 2023). Now, asset managers need to find out where they can save money and try to implement new solutions and technologies. Gehra points out that transfers of securities or shares from one account to another may take up to four weeks, highlighting the need for improvements in the efficiency of the processes.

This need for cost savings in the bond market could be one of the most significant incentives for firms to implement the tokenization of bonds into their businesses. Different reports and papers from Roland Berger, Porsche Consulting, and Finoa & Cashlink have reported cost savings of between 24% and 65% throughout the value chain of the bond market (Cashlink, 2020; Gysegem & Patoul, 2021; Tewes, Bauer & Holz, 2023). Gehra is currently working on the tokenization of bonds with Immutable Insight, where they have looked at different categories involved in the process and how the tokenization of bonds would affect their cost.

> *The final project that we have from the project with Finoa and Cashlink there are three different categories: the bank, the purchaser, and the book-running bank. For the book-running bank, this is a bad deal because they actually lose revenue, and that is why they are also against it. The issuing bank goes down from a cost of around 1,5% of the volume to a flat fee of around 100-150k euros. Whether or not this is a good or a bad deal depends on the size of the bond. For most cases, this is a good deal. Because you are at flat fee rather than percentages. For the book-running bank, it is a problem because they get a percentage of the amount paid by the issuer, and if the issuer pays a significantly less amount, they lose a lot of money. And thirdly it is the buyer that needs to pay the custodian to hold the traditional bond versus the online blockchain token. And it has a magnitude to be of up to 90% cheaper.*
>
> *- Katharina Gehra, Immutable Insight*

The reduction in costs for the issuing bank from 1,5% of the volume down to a 100-150k euro flat fee will be profitable for the issuer in most cases where the issuance size is larger than €10 million, which they often are when the average global size of corporate bonds is around $20 million (Çelik & Isaksson, 2020). Considering the issuance of an average corporate bond of $20 million, the cost savings for the issuing bank from using tokenization would be in the area of 100-150k dollars, or approximately 50% to 66% cost savings (assuming here that 1 dollar equals 1 euro for simplicity of the example).

6.2.3 Programmability and smart contracts

Another aspect of tokenization and the use of blockchain is the programmability and use of smart contracts. As elaborated in Chapter 2, there are different possibilities within the programming of tokens, both for the securities and payment, potentially with a wholesale CBDC. Programming the tokens to perform tasks that intermediaries did manually before, automatically, and instantaneously when conditions are met will eventually increase efficiency and create a smooth automated system for the markets. Gschnaidtner spoke about what he believes the effect of the programmability of securities and wCBDC will be.

> *(...) A positive effect of the wholesale CBDC would be if it's designed this way if it could allow for programming and stuff like smart contracts. And I think that would be interesting because in particularly the financial markets. You would get rid of all these central institutions where clearing is taking place. So you wouldn't need any clearing*

institution anymore. As well as securing your money somewhere. (…)

You would basically not need that anymore because you could program that in a smart contract, and that would lead to changes in the market. Again, what you need is somebody who does program all that stuff; you need somebody who's actually checking it. So you need regulation. But if that's in place, and I don't think that's going to be a big issue, then this would actually lead to a much more efficient financial market. And that's clearly also an advantage of bonds. So, if you're in the bond market, you're usually dealing with high amounts of money. And this would make things quite easier.

- *Christoph Gschnaidtner, T*echnische Universität München

The disintermediation of clearing institutions that Gschnaidtner talks about here, when we no longer need them to handle the transactions, might be a challenge for implementing tokenization and DLT into the value chain. Even though the technology might make the bond market faster, cheaper, and more efficient, these intermediaries may be reluctant to invest in this new technology. The same will account for the "bad deal" for book-running banks that Gehra points out when you reduce their income by introducing a flat cost rather than a variable cost of the issuance volume. They will probably lose revenue by introducing the technology and, therefore, be reluctant to invest.

6.2.4 Regulations

The regulations that Gschnaidtner was asking for are up and coming in the EU. The regulation (EU) 2022/858 was announced in May 2022 and is called Pilot Regime for market infrastructures based on distributed ledger technologies. While the MiCA regulation establishes the legal framework for issuing and trading unregulated crypto assets such as stablecoins, the DLT Pilot Regime aims to provide a regulatory sandbox for financial institutions and authorizations for the trading and settlement of DLT-based financial instruments. As the Pilot Regime points out, the current financial service legislation is not designed with DLT in mind, and there is a lack of financial market infrastructures that use DLT. It points out that there are no transparency, reliability, or safety requirements imposed on the protocols and smart contracts of crypto assets that underpin as financial instruments. This is what the Pilot Regime aims to solve (The European Parlament & Concile of the European Union, 2022, p. 151/2).

The Pilot Regime is establishing the regulations on how the market infrastructures should establish their IT and cyber agreements. As it is stated in the regulation on point 41,

"Those arrangements should also ensure the continuity and continued transparency, availability, reliability and security of the services provided, including the reliability of any smart contracts that are used, irrespective of whether those smart contracts are created by the DLT market infrastructure itself or by a third party following outsourcing procedures" (The European Parlament & Concile of the European Union, 2022, p. 151/8).

This demonstrates that there are processes in the EU to establish regulatory rules on how these distributed ledger technology market infrastructures should operate and follow the regulations when constructing the smart contracts and building up the DLT-based infrastructure.

The regime also limits bonds and other securities trading on DLT market infrastructures. For instance, if shares are to be traded or recorded on a DLT infrastructure, the issuer's market capitalization needs to be less than €500 million. For bonds and other forms of security debt the issuing size cannot exceed €1 billion (The European Parlament & Concile of the European Union, 2022, p. 151/14). The regime is a comprehensive regulation that takes on some of the regulatory challenges faced by introducing DLT technology in trading and recording securities.

The financial institutions operating under the Pilot Regime must abide by various rules to maintain the approval to operate. As of 23. March 2023, institutions who want to operate under the regime can apply for the pilot project. The institutions need permission to participate. Three years have been set aside before the European Supervisor Authority (ESMA) will report to the European Parliament and the Council of the European Union on the result of the pilot. Based on the result from this report, a decision on whether the regime under the pilot regulations is to be extended, expanded, amended, made permanent, or terminated (Dutch Authority for the Financial Markets, 2023).

6.2.5 Familiarity with the technology

Another problem that interview subjects have highlighted is that people in the business of bonds and securities need to become more familiar with the technologies and the potential disruptive outcome of introducing them into the market value chain. Gschnaidtner explains some of the reasons for this in short terms.

> *(...) I was giving a webinar in the morning with investment bankers, and even they didn't know what blockchain technology actually was before the webinar. Now I hope they know. So what I mean is, like even people who are in the business, they are not familiar with the technology and that is a challenge.*
>
> - *Christoph Gschnaidtner, T*echnische Universität München

This illustrates that there is a job to be done in educating participants in the market if blockchain is a technology to be implemented in the investment banking and bond markets, as well as being a trusted technology. The misunderstanding that blockchain technology is equivalent to speculative cryptocurrencies is common among many people. In a survey of decision-makers in fintech and financial services organizations conducted by FTI Consulting, more than 80 % of the participants agreed that "people continue to struggle to distinguish between blockchain technology and cryptocurrency." This could be a significant hurdle before implementing blockchain and DLT into the bond markets (McNew et al., 2023). Introducing the regulations on crypto assets by MiCA and the DLT Pilot Regime on market infrastructures based on DLT may help overcome these hurdles. They may make it easier for financial institutions and corporate investors to understand and trust the technology and the products developed using DLT infrastructure.

6.2.6 Liquidity

Liquidity in the bond market is essential for the price of the individual bonds. An increase in liquidity in the bond market will lead to a rise in the price of the bonds. Earlier research shows that the liquidity effects in the market account for approximately 14% of the explained market-wide corporate bond yield (Friewald et al., 2013). As bond price and yield are highly related, the level of liquidity changes the price. The same research pointed out that in financial crises, all bond prices decline due to increased illiquidity, and following a flight-to-quality will happen. This means that the price actions on investment-grade bonds are less than for speculative-grade bonds, and the liquidity effect is higher here. Therefore, if blockchain technologies could increase liquidity in the bond market, it would be an incentive to implement it.

We asked Gschnaidtner if the advantages of tokenizing bonds might lead to increased liquidity in the market. He argued that the fractionation of securities using tokenization would allow for more liquidity in some markets. However, he did not see that happening for the bond

market because people must be willing to trade these fractioned tokens, and the bond market is relatively illiquid anyway. However, he argued that another aspect of tokenization might increase the liquidity:

> *Where it becomes definitely interesting is in terms of that it's cheaper to issue a bond, it's definitely more efficient to do all the handling, and at some point, if enough people are willing to buy that, then this might definitely increase liquidity. But at the current point, I don't think it's an issue breaking down and constructing smaller tokens. It's much more a demand and supply issue.*
>
> - *Christoph Gschnaidtner, T*echnische Universität München

If blockchain is to succeed in the bond markets, it may need to increase liquidity. As Gschnaidtner points out, the cost savings and efficiency in the handling might lead to increased liquidity. In the next chapter, we will look at the implementation of the tokenization of bonds and the use of DLT platforms throughout the post-trade value chain of bonds and see examples of how much costs can be saved and how it will increase efficiency.

7. Case of Tokenized Bonds using Wholesale CBDC

7.1 Value Chain

The bond market contains a complex structure of stakeholders throughout the bond's value chain and lifecycle. We looked at the different steps the bond goes through from issuance until maturity in Chapter 2.5.3. The different stages of the bond lifecycle also bring challenges and costs. This small case will shed light on some of the main difficulties with the phases and present an approach to how DLT and tokenization technology can address these challenges and improve cost savings in the different stages.

The six value chain categories are organized by intermediaries like banks, issuers, agents, investors, custodians, central securities depository, and central counterparty clearing houses. These intermediaries organize the issuance process, bond trading, settlement, and asset service for the bond issuer. The intermediaries also charge fees to the issuer and the buyer regarding the custody of the security. Some of the costs vary a lot from one bond to another. The fees are often a result of bargaining between the different parties and depend on what type of bond it is, what rating it has, and what bank is used to issue the bond. One European Corporate Governance Institute report looked at 9356 bond issuances from 1970 until 2015 in 1696 U.S. firms, whereas 7971 issuances gave the basis to evaluate the underwriting fees that the book-running bank charges the issuing corporation. The report showed that “Issuers facing underwriters with the highest bargaining power have a $1,5 million higher issuance cost, or about 16% relative to the average issue” (Manconi et al., 2019).

They found that the average fee charged was 0,88% of the amount being issued, whereas the maximum charge was 3,5% (Manconi et al., 2019). The study results align with Katharina Gehra´s statement in the interview, where she said the book-running bank charges a fee of around 1,5% of the volume. Some book-running banks would charge a fee of about 1,5%, as shown in the report, but the average from the sample of bond issuances is closer to 1%.

This shows that the fees related to the issuance of a bond could be substantially hefty in terms of the size of the bond. For instance, for a bond issuance of €500 million and a charge at an average of 0,88%, the issuer will be charged an underwriting fee in real terms of an average €4,4 million, while a €100 million bond on average charges €0,88 million.

The different intermediaries and book-running banks face various challenges throughout the issuance when using today's traditional methods and technologies. A report by J.P. Morgan and BCG, “The future of distributed ledger technologies in capital markets,” from 2022, discusses the stages in the lifecycle of bonds and what challenges or “pain points” these stages face (Ramachandran et al., 2022). The report also undertakes a case highlighting how these pain points can be approached using DLT platforms and blockchain technologies.

7.2 Challenges

7.2.1 Issuance

Issuing a bond involves stakeholders, such as the issuer, underwriter, legal firms, and agents. These stakeholders often maintain their data in separate locations or what may be called a siloed data structure. With a structure like this, duplication of effort, errors in data entry, and human errors could be possible scenarios. The issuance process is also costly and could lead to a lower frequency of issuance and create barriers for smaller issuers or those who issue bonds infrequently.

7.2.2 Trading

The bond market is less liquid than, for example, the stock market. It contains fragmented liquidity, making buying or selling bonds difficult without impacting the price. Much of the trading of bonds is done OTC, and the trades are often done through the broker-dealer network, Bloomberg messaging, or over the phone. This can be slow and inefficient and may lead to delays and errors in trading. Due to OTC trading, the pricing of the bonds lacks real-time pricing data, which can lead to the investors not getting the best price. The trading of bonds OTC is also restricted by trading hours, which can be a disadvantage.

7.2.3 Clearing and settlement

The extended clearing and settlement time at T+1/T+2 creates a risk to counterparties. The counterparty risks in the case of clearing and settlement are that if one of the parties defaults during the period from the execution of the trade until the final settlement, the other party could suffer significant losses. The different parties also need to communicate, and discrepancies that require manual corrections can be time-consuming when having a siloed data structure.

7.2.4 Custodians

Transferring bonds from the seller's custody to the buyer's custody is fragmented and involves different parties and manual steps. This slow process increases the risk of miscommunication and errors. If buyers hold their bonds in other individual data repositories, it could be challenging to trace the chain of custody of the bond. The low transparency creates complexity if the chain needs to be investigated.

7.2.5 Asset servicing

The lack of a unified data repository for asset servicing can lead to inefficiencies in communication about corporate actions, coupon payments, and other essential bond elements. These actions from the issuing corporation often require manual intervention by the issuer's agent, which can be time-consuming.

The challenges in the value chain highlight the potential need for more efficient, transparent, and automated processes. DLT and blockchain technologies can address some of these challenges. In this case, we will look at how this can be addressed using tokenized bonds and DLT platforms for its value chain. We will also look at some cost savings in the different categories of the value chain faces while implementing the new technologies compared to traditional bonds.

7.3 DLT, Tokenization, and Wholesale CBDC

J.P. Morgan and BCG illustrate and explain the lifecycle of traditional corporate bonds and DLT-based corporate bonds. Figure 7 displays the bond lifecycle before and after the tokenization of the bond and DLT platforms to automate processes.

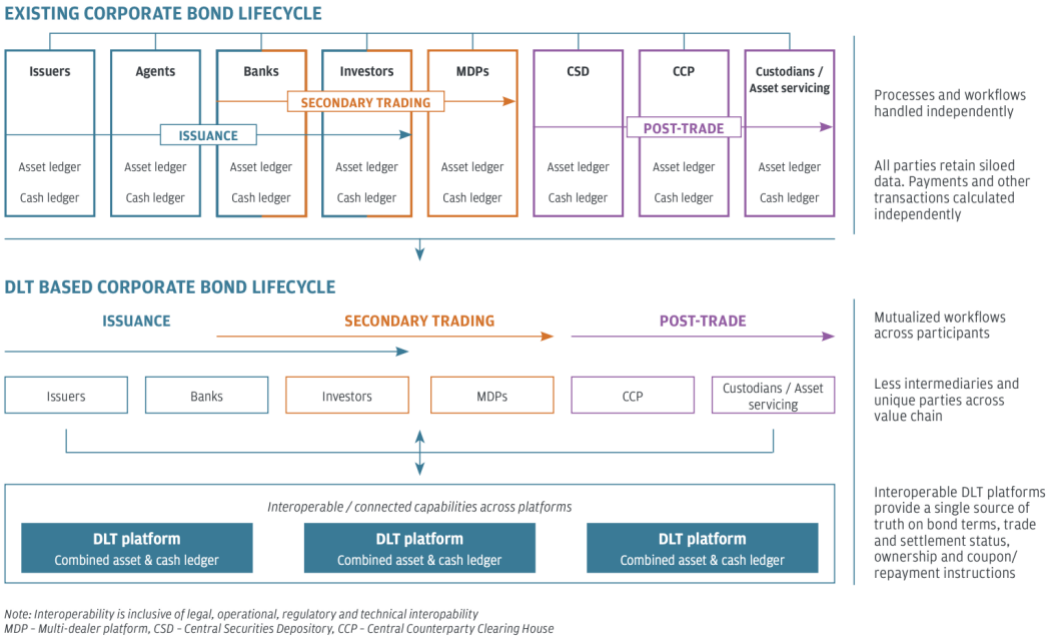

Figure 7 - Lifecycle of traditional corporate bonds and DLT-based corporate bonds. (Ramachandran et al., 2022).

Traditionally, the bond lifecycle contains siloed data structures where each participant in the value chain often uses individual data systems to obtain and process the data. There are different challenges with such a structure, which leads to participants calculating the transactions and payments independently. Introducing an interoperable DLT platform can address this challenge through automation so that value chain participants can access shared data and records of transactions and communication.

The transition into using DLT platforms, tokenized bonds, and a DLT-based wholesale CBDC will reduce the complexity of the lifecycle. The DLT platform provides a single source of truth on the terms of the bond that is accessible to all parties of the value chain. The settlement will be executed immediately due to an atomic swap between the tokenized bond and the wCBDC. Custody of the securities becomes simpler when the custodians take care of private keys that access the wallets where the tokenized bond security is stored. They do this because if private keys are lost or stolen, the security can be irretrievable for the owner, and the custodians provide the safekeeping of the customer's bonds. The ownership of the bonds is also registered on the platform and is continuously updated if ownership changes are made. When the smart contracts of the tokenized bond are correctly created, the custodian does not need to ensure that the asset servicing is done at specific times. Coupon payments and different payment instructions are executed automatically and are made when the pre-programmed requirements

are fulfilled. If changes are to be made to the conditions, the code needs to be updated, and the bond owners will be informed about the changes.

As discussed in Chapter 5, the settlement of the tokenized security in return for money will happen instantaneously. This removes the counterparty risk associated with a T+1/T+2 settlement time. The reason why wCBDC enables instant delivery versus payment is that wCBDC is compatible with settling tokenized transactions. When the investor has access to wCBDC through its bank, and the bond is tokenized, the exchange of wCBDC and the tokenized bond happens instantaneously.

7.3.1 Settlement of tokenized bond

Bank of International Settlement conducted a proof of concept on settling a tokenized bond using wholesale CBDC in 2020. The proof of concept demonstrated how the transfer and settlement of a delivery of a tokenized bond versus a payment with a wCBDC are being executed using a notary node to confirm the transaction's validity. Figure 8 illustrates the settlement of a tokenized bond using a wCBDC from Project Helvetia Phase 1. Here, one can see that Bank 1 holds the tokenized asset and sends a delivery versus payment instruction to Bank 2; if Bank 2 wants to execute the trade, the bank sends a receipt versus payment instruction back to Bank 1. Then, the notary node checks if both parties have not double-spent their tokenized assets in the network, and it ensures finality (this could also be executed on a permitted blockchain). If the check is confirmed, the transfer is completed immediately. This is an example of an atomic settlement of a tokenized asset using the wCBDC (Bank of International Settlement Innovation Hub, 2020).

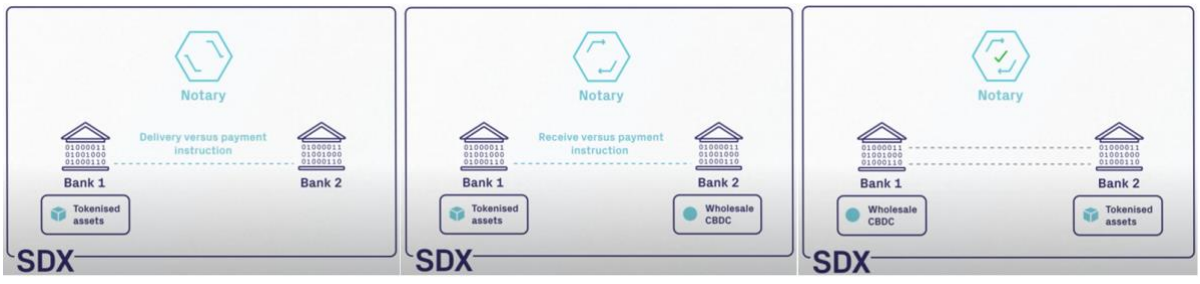

Figure 8 - Settlement of tokenized bond using wholesale CBDC. (BIS Innovation Hub, 2020, 1:08)

As we see from the example, the clearing was done in the notary node, and the settlement illustrates a significant improvement in time consumption and automation. DLT and tokenization of a bond combined with a DLT-based wholesale CBDC are efficient because all

processes are executed on the DLT platform and follow the rules that are programmed on it. The project Helvetia used Corda R3, a DLT platform specialized in the financial services (Bank of International Settlement Innovation Hub, 2020).The SDX trading platform is developed by the company operating the Swiss Stock Exchange, SIX. Currently, the SDX platform relies on privately issued forms of money to settle tokenized assets, but Project Helvetia proves the feasibility of settling tokenized assets using wCBDC. 02.11.2023 SIX announced that the project is entering phase III, where the Swiss National Bank (SNB) will launch its wCBDC pilot for the first time with real wholesale CBDC in the Swiss franc (Six Group, 2023).

7.4 Cost Savings

The cost savings from utilizing tokenization of assets in combination with DLT-compatible money have been proven in different reports, often from consulting firms. Most reports show that the cost savings vary between the various participants in the value chain. Issuance, trade, clearing and settlement, custody, and asset servicing all face separate cost savings when using tokenization of the assets. It must be mentioned that the cost savings in the value chain are not directly transferable to the bond markets when the reports look at the cost savings in the value chain for the tokenization of various securities. The different securities are bonds, stocks, funds, real estate, and other assets. The reports give a broad overview of savings on each post, ranging with high deviations from the minimum and maximum savings. Regarding the issuance of bonds, the amount of savings would vary from issuance to issuance mostly because the intermediaries charge different fees to their clients and depend on the volume of the asset and bargained deals with the issuer.

Two open papers and one small summary of a study with restricted access gave us insights into how the cost savings spread among the different participants and categories in the value chain. In 2021, the consulting firm Roland Berger published a paper by the partner Frederick Van Gysegem and the CEO and Co-Founder of Keyrock Kevin De Patoul on “The Tokenization of the Economy and its Impact on Capital Markets and Banks.” The paper looked at the future impacts of tokenization on the equity trading market. Cost savings were estimated to be 24% in the overall value chain from a long-term perspective for the market (Gysegem & Patoul, 2021). In 2023, Porsche Consulting posted a paper on “Security Tokenization; How to unlock hidden value by moving stocks, bonds and funds on the blockchain.” The paper aims

to show that DLT offers new and exciting opportunities for a wide range of market participants. They found that the total cost savings throughout the value chain could reach 35-50% compared to traditional costs (Tewes et al., 2023). The earliest study on cost savings using tokenization of assets and DLT came from Finoa & Cashlink in 2020. The study was restricted to their clients, but summaries show findings of a cost-saving range of 35-65% compared to traditional costs in the security markets (Cashlink, 2020; Finoa, 2020).

The different papers and studies look to varying savings throughout the value chain. For the Roland Berger paper, they looked at these different categories in the post-trade value chain: clearing, settlement, custody, and asset servicing. They also added the cost of risk, which they quantified to be a 100% reduction in the overall costs. The Porsche Consulting paper reported the potential savings of stocks, bonds, and funds for the general security markets and was using a different value chain than Roland Berger. Porsche's value chain contained savings in seven different categories. Trading and brokerage, Collateral Management and transaction service, Clearing, Settlement services, Corporate actions, Tax reporting, and other support services. Below are the different cost savings for the two consulting firms, Porsche Consulting and Roland Berger, illustrated in Table 2 and Table 3.

Roland Berger			
Equity trading value chain:	Total costs	Total cost savings	Category savings
Clearing	655	655	100%
Settlement	1447	289	20%
Custody	16850	1685	10%
Asset servicing	26	10	38%
Price of risk	Not a part of the value chain	1970	100%
Sum	18978	4614	24%

Table 2 - Cost savings using tokenization and DLT. (Gysegem & Patoul, 2021).

Porsche Consulting			
General security trading value chain:	Weighted Costs	Average accumulated cost savings	Category savings
Trading & Brokerage	20%	3,0%	15%
Collateral Management & Transaction service	5%	3,0%	60%
Clearing	10%	10,0%	100%
Settlement services	16%	7,5%	47%
Corporate Actions	17%	11,5%	68%
Tax reporting	14%	4,0%	29%
Other support services	18%	3,5%	19%
Sum	100%	43%	

Table 3 - Cost savings using tokenization and DLT. (Tewes et al., 2023)

Savings from the equity trading paper from Roland Berger estimates a total cost saving of 24% based on a long-term perspective with high adoption of tokenization in the value chain. The paper forecasts the adoption of the technology to be 90-100% by 2030. However, the numbers from the cost savings could be applicable to represent the initial cost savings from implementing the technology in one market section. Even though the paper looks at the post-trade equity market, the value chain is somewhat comparable to the bond-issuing value chain discussed above.

The Porsche Consulting paper generally looks at the tokenization of security trading for stocks, bonds, and funds. Also, it includes trading and brokerage, collateral management, and transaction service, which differs from the value chain Roland Berger uses to calculate the total cost savings. Porsche Consulting estimates actual cost savings to range between 35% and 50% compared to traditional costs. The average cost saving using tokenization will be approximately 43%, as Table 3 displays.

Comparing the two papers, the categories in the value chain from Roland Berger, custody, and asset servicing can be compared to those in the Porsche Consulting value chain, corporate actions, tax reporting, and other support services. From Tables 2 and 3, we can see that the total cost savings originating from custody and asset servicing in Roland Berger´s paper represents 37% of the total cost savings. From the Porsche paper, cost savings originated from corporate actions, tax reporting, and other support services, representing 45% of the total cost savings. This is quite a similar portion of the total cost savings, even though the two papers compute an average difference in cost savings at 19%, 24% versus 43% savings. In the clearing category, the two papers agree that using tokenization on securities removes all clearing costs, with a 100% cost reduction in both papers. The settlement and settlement services are different, 20% versus 47%.

Why this is the case is complex to say when the data foundation for the paper is unavailable to the public. Some possible reasons they differ could be that they look at different sectors for tokenization, equity trading for Roland Berger, and stocks, bonds, and funds for Porsche Consulting. The assumptions that the two papers use are also unknown, and there may be differences in the technology that they think will be used when the adoption of tokenization accelerates. However, the cost savings of using tokenization on bonds would be acceptable to say that may be positioned somewhere between the two papers' results, between 24% and 43%. This is also in line with the first study from Finoa & Cashlink, reporting a cost saving of between 35% and 65%, even though it is positioned in the lower sector of the cost savings.

7.5 Summary

What we can see from this small case is that tokenization of bonds in combination with wholesale CBDC affects all parts of the value chain, creating a less siloed data structure and bringing promising interoperability between the different intermediaries in the value chain of a bond issuing, as well as other securities. This interoperability interface by using DLT platforms creates less friction between intermediaries and fosters efficiency, transparency, and reductions in cost in the value chain. Assuming that the DLT platform is unified across the value chain and that the technology does not create a new siloed data structure. This is one of the problems that the technology aims to solve, not create.

The cost reduction throughout the value chain could potentially reach around 24% to 43%. Many factors affect the total cost savings in the bond market due to different prices from

stakeholders in the value chain. However, a range of savings between 24% and 43% is likely due to automation and increased efficiency in clearing, settlement, and custody of the bond security. These savings assume the potential and not necessarily the real-world accumulated savings due to the cost of implementation and the fact that the current financial infrastructure is not ready for adopting tokenization and DLT tomorrow.

8. The Interplay between DLT-based wholesale CBDC and Tokenized Bonds

One of the main challenges the tokenization of bonds faces is that economies may need a tokenized form of wholesale money backed by the central banks. To succeed, the payment form must be entirely stable against the specific currency to mitigate the risks associated with untrusted solutions. This needs to be in place to solve the payment leg in bond settlement fully. In the future, central banks across different countries may issue a wholesale CBDC. The potential wCBDC could make the tokenization of bonds and other securities more accessible to financial institutions. The interplay between tokenized bonds and wCBDC can allow for opportunities in the market, but at the same time, new challenges and problems need to be solved for it to be implemented by the value chain.

8.1 Settlement

For the tokenization of bonds and the use of wholesale CBDC to have value, it must be able to solve the payment leg. The settlement time needs to be reduced from T+2 to T+0. Otherwise, the settlement system does not need to be updated. For the settlement time of tokenized bonds to be T+0, both the wCBDC and the tokenized bond must be compatible. Some of our interview objects argued that the current settlement time T+2 functions appropriately today, but improvements could be made. Still, implementing the new technology is a move towards efficiency and risk reduction rather than trying to solve an urgent problem. Ole Einar Stokstad argues that the current T+2 settlement system functions adequately, and the need to achieve T+0 is currently overstated in the financial markets. He suggested that the drive towards instant settlement is more about improving efficiency and reducing risks and costs than solving a substantial problem, especially for the bond market.

8.1.1 Cost of implementation

This thesis discusses how the reduction in settlement time will bring benefits in terms of costs and reduction in counterparty risks. Still, we have yet to mention the short-term costs of implementing this new technology in all aspects of the value chain. Research clarifies that tokenization and a DLT-based payment method will improve efficiency and reduce costs throughout the value chain in the long term. However, the cost barriers to implementation in the short term are less discussed in research. The focus is often on the benefits of cost

reduction, settlement efficiency, and reduction in counterparty risks throughout the value chain. Suppose the effort needed to implement these systems and bring assets onto DLT platforms is substantially more significant than the cost and efficiency gains. In that case, it might not be as appropriate to use the technology to reduce the settlement time and improve the processes in the value chain.

Lasse Meholm pointed out that designing and implementing the RTGS system with T+2 settlement time in 2014 brought significant costs. The same accounts for the recent transition from TARGET2 to the currently operating T2 system, where improved payment security, transaction costs, and efficiency in cross-border transactions were implemented (ECB, 2023). Even though the total costs of implementation are difficult to quantify, these complex systems require a lot of effort from central banks and all parties involved, which implies a substantial cost of implementation. However, the total costs of the updates and changes on the RTGS systems are most likely estimated to be less than the long-term benefits of the updates. Meholm explained some of his opinions on why the technology is still not implemented widely.

> *The cost of creating this system was once significant. And when you say that the new technology is cheaper, the bank says: okay, but now we've spent a lot of money, and it works, and we don't want to spend money on improving something that works. If the system had been designed today, I believe that blockchain would have been used, but since it already exists and functions, there is no point in paying for a new technology to replace the current one. The big banks have shareholders who expect dividends and an increase in the share price. There is an extreme focus on making money. So, if they can save a few million today by not using blockchain, they'll do it.*
>
> - *Lasse Meholm, Norges Bank*

This is the concept of sunk cost fallacy, which implies that committing to the current plan and what is currently working is justified because resources have already been committed. This possible “mistake” could result in inappropriate long-term decisions based on the short-term conditions and costs that have already occurred. As this fallacy implies, the decision-makers need a long-term perspective to make the most rational choices. It is also important to note that the sunk cost fallacy is not always a mistake and that there are times when it is reasonable to continue with the current plan. For instance, as discussed, if the cost of implementing a new technology outweighs the benefits, sticking with the current system would be rational. And

since the future benefits of implementing the new technology are uncertain, it may be appropriate to wait until the probabilities of the outcome have been more favorable.

T+2 had significant advantages compared to the previous T+3 settlement time and was an essential step towards a more efficient financial market. Today, the potential future introduction of T+0 could outperform the benefits of T+2 in the long term. Technically, we can use the existing technologies within tokenization and DLT that we have discussed to solve the problem by reaching T+0. Several pilot projects and proof of concept have proved the benefits of using the technology and reaching the T+0 settlement time (BIS, SIX group, SND, 2022). However, there are a lot of hurdles before it is practically feasible. Trusting the consensus mechanisms, trusting the issuer of the tokenized bond, making sure that custody of the wallet is being taken care of in the same safe way as traditional custody, interoperability between the intermediaries in the value chain needs to be flawless, and the system requires to always function without failure. The complexity of implementing the T+0 settlement of securities and bonds is a time-consuming and resource-intensive process that will take years to design and implement with high adoption rates.

8.2 Interoperability

In the quest to harness the potential of tokenization in connection with wholesale CBDC, interoperability across diverse platforms within the value chain is fundamental for its success. Many central banks with their own currency may develop their solutions to wCBDC individually with some interaction with other central banks, possibly through the BIS Innovation Hub. The final solutions provided by the different central banks are likely to be developed using a variety of technological approaches. In the financial markets, unique tokenization processes, solutions by custody providers, and various settlement systems across borders will be observed. These disparate solutions introduce a risk of reinstating the siloed structure that DLT aims to solve. This paradox underscores the critical need for a common language across DLT platforms or languages that can communicate appropriately. This includes both the wCBDC and tokenization technologies to prevent the fragmentation of the data structure in the value chain.

8.2.1 Optimal interoperability

The promise of cost reductions, efficiency, seamless cross-border transactions, and frictionless settlements relies heavily on the interoperability of the individual solutions provided by central banks, private financial institutions, and intermediaries within the value chain. Ideally, all platforms should operate on one standard DLT system, and all wCBDC should be based on the same technology, and the same should be for tokenized assets. This is most likely just a dream world and would be unachievable taking the current siloed and complex structure of the markets into account; the reality is far from this utopian scenario.

But one thing is sure: cross-border transactions between individual currencies using wCBDC must be interoperable. If they are not interoperable, the value added from introducing the technology will be significantly reduced. Compared to the current system, the benefits of the technology become limited by internal transactions within the same currency. Individual central banks must be interoperable for the settlements to run without frictions—the same accounts for the interoperability between different DLT platforms and intermediaries in the value chain.

The individual wCBDC settlement platforms must be designed for interoperability. It needs to synchronize data across different platforms, handle system errors, and adjust the technical standards. Creating a platform system like this will require a lot of collaboration between platform creators; a great effort must be put into developing technical and practical solutions before they can be launched in the market (BIS, SIX group, SND, 2022). Even though some institutions, like BIS, are working on the interoperability challenge, other focus areas take up the attention in most projects on wCBDC and tokenization. Alexandra Thome expresses this in our interview; “With a lot of projects that I am seeing now, interoperability is not really one of the prioritized topics that you are looking at.” This implies that many of the projects are currently working on solving the main problem of their interest and are probably overseeing new emerging issues like interoperability and other risks, ignoring the need for different systems to work together.

Throughout the active ongoing projects with wCBDC and tokenization of bonds, different consensus mechanisms, token standards, blockchains, and ways of dealing with the legal work are used. Many other practices and methods of constructing solutions with blockchain, tokenization, and DLT exist. The reason why we have so many ways of creating solutions is

mainly because different technologies try to fix specific problems. They have distinct features that apply more to some issues than others; therefore, there is no such thing as one unified technology that solves all issues in the market. And because of this, the interoperability problem between solutions occurs. The key takeaway is that new unforeseen issues arise when you try to solve one problem. One possible solution to interoperability is to collaborate on constructing the solutions. Goldman, Deutsche Börse, and 30 other firms have recently joined a network, working on institutional blockchain interoperability, but this is still early, and according to a report from Moody´s, achieving interoperability between conventional exchanges requires development on the technology as well as regulatory support (Moody´s Investors Service, 2023).

8.2.2 Interoperability today

Even though interoperability is a significant challenge for using blockchain, tokenization, and DLT to execute transactions across different platforms and systems, we have seen similar challenges being solved throughout history. Society for Worldwide Interbank Financial Telecommunication (SWIFT) and Single Euro Payments Area (SEPA) are the most used forms for cross-border transactions. These two systems aim to solve interoperability across borders and provide safe and reliable international transfers (SWIFT, 2023). SWIFT is working on international cross-border transactions and has solved interoperability problems when dealing with different platforms across the individual systems in each country they cover. SWIFT has over 11,000 banks in more than 200 countries, and the fact that the system is reliable and trusted by its users is an example of how these interoperability problems are manageable (CFI Team, Unkown Date).

There are also interoperable projects within DLT solutions that are currently trying to approach the challenges with communication between blockchains. As Meholm mentioned, the Norwegian Bank worked on making cross-border transactions with rCBDC using Hyperledger Besu on the Norwegian solution, Corda on the Swedish solution, and Quorum for the Israelian solution. The project showed that the interoperability between the different platforms' use of various technologies worked and that they could communicate across the technologies. Hyperledger Besus is compatible with several consensus mechanisms like PoW, PoS, and proof of Authority. It has a comprehensive permissions scheme for use in a consortium blockchain environment. It is a network where the permissioned participants can control who gets access to open addresses inside the blockchain (Meholm, 2023). In a consortium

environment like this, the financial institutions that participate can have their private blockchain where pre-selected sets of nodes on the private blockchain can control the consensus protocol of the entire consortium blockchain (Dawson & Baxter, 2019). This shows that efforts are being and have been made to try to solve interoperability problems within the blockchain and DLT platforms. As Meholm mentioned, Norges Bank will explore different possible solutions, but finding the perfect technology is difficult or even impossible (Meholm, 2023).—the same accounts for different token standards to be used. What type of token standards are being used in asset tokenization is essential to make interoperability between wCBDC and the tokenized asset as easy as possible. If they are not compatible, it introduces a new challenge.

8.3 Tokenized Bonds and Cash Leg Alternatives

When securities such as bonds are converted to digital tokens representation and issued on a DLT platform, it will be possible to allow programmable settlement conditions to be embedded directly into the tokenized bonds. This leads to the possibility of atomic settlement and reduction of settlement risk. However, asset settlement includes two legs: the asset and the cash leg. The cash leg must also be tokenized for financial institutions to fully benefit from tokenized bond features. This can be done through DLT-based wholesale CBDC, stablecoins, or tokenized deposits.

8.3.1 Stablecoins as the cash leg

Stablecoins aim to have a stable value relative to an underlying asset or a pool of assets, and provide stability compared to volatile crypto assets (Hebert et al., 2023). How stable a stablecoin actually is depends on what the underlying asset it is pegged against actually is. Security token company Ondo Finance recently launched a tokenized fund allowing stablecoin holders to invest in bonds and US treasuries. Smart contracts are used to conduct compliance reviews and on-chain trading between investors. Ondo Finance claims investors' funds are secure in the event of bankruptcy by keeping the investors' funds as a separate entity from the LLC (Ondo Finance, 2023). Still, it may not necessarily mean that the funds are completely secure. In the event of bankruptcy, investors might face legal challenges against creditors who can put a claim on the funds, leading to a potential loss for the investor. In addition, stablecoins are not entirely risk-free as their value is pegged 1:1 to an underlying asset; the underlying

asset's value may change during market fluctuations, leading to volatility and risk for the investors. In addition to credit risk, underlying risk, and counterparty risk, lack of regulation has posed a potential risk. As mentioned earlier, events like the Terra Classic USD collapse have shown that stablecoins are not always stable. This is probably because they are not using assets like USD deposits as collateral for backing their value but rather use volatile assets.

8.3.2 Tokenized deposits as the cash leg

Tokenized deposits are another cash leg option for investing in tokenized bonds. By being directly pegged against bank deposit balances, tokenized deposits avoid some of the risks faced by stablecoins regarding underlying risks. However, while tokenized deposits are asset-backed, settlement using tokenized deposits still ultimately relies on the liquidity and performance of commercial banks. Uniformed standards and coordination between commercial banks could lead to efficient tokenized bond markets. However, with tokenized deposits, validation against internal bank records is still required after the blockchain transfer. This process introduces counterparty risk and lags in settlement compared to a direct settlement with central bank reserves using wCBDC. Tokenized deposits could face challenges regarding adoption as investors may be unwilling to take on risk by having exposure against a single private bank’s tokenized deposit solution rather than settling using central bank reserves.

8.3.3 Wholesale CBDC as the cash leg

Lastly, a DLT-based wholesale CBDC is a possible solution for the cash leg problem and will likely be the most robust option out of the three alternatives. The wCBDC will enable delivery versus payment settlement of tokenized bonds with atomic swap. With a simultaneous swap of tokenized bonds and tokenized wCBDC, counterparty risk will be eliminated. Nevertheless, developing seamless links between legacy clearing systems, wCBDC platforms, and tokenized asset environments is still complex. There must be great coordination between central banks, regulators, and market infrastructure between different nations to build a seamless system. There has been multiple proofs of concept projects proving the capabilities of CBDC and BIS projects, such as Jura, Helvetica, Icebreaker, and Genesis, have shown that CBDC can be used for settlement of tokenized bonds, cross-border payment, and settlements across different currencies, eliminating settlement risk in large-scale transactions. However, wCBDC is still

years away as policy changes and legal and coordination hurdles must be solved before wCBDC can settle tokenized bonds in the economy.

8.4 Feasibility

Although the technological foundations for settling tokenized bonds using DLT-based wholesale CBDC exist, implementing such systems on a large scale in the economy still poses significant challenges. A question up for debate is whether the cost savings and efficiency gains from implementing the technology are so substantial that it overgoes the costs and time of implementation in the long run.

Realizing the potential efficiency gains and risk reduction of atomic settlement relies on overcoming several barriers regarding legal, regulatory, and coordination issues across different entities. Banks, trading partners, infrastructure providers, and government authorities must work together, agree on standards, and create new processes to have legacy systems working with new technology. This process will be costly and time-consuming. One additional concern for the implementation is that there is little to no initiative from investment banks lobbying for the move towards tokenization of bonds and wCBDC. Two main factors might cause this. First, implementing this may generate lower earnings for the banks as many of the processes will be automated, meaning lower fees for the banks in exchange for higher yields for the investor. Secondly, it might be due to a lack of knowledge or interest, as many of the decision-makers do not know about the potential of this technology.

Katharina Gehra was convinced that the older the board members of a company, the less likely they would be willing to implement tokenization technologies into their businesses. It is also an impression that the biggest banks and financial institutions must take the lead in these implementations. If they have board members at a high age, they will probably be less open to the new technology.

> *The big banks are also being seen as the big leaders and the somebody that needs to do it first, such as Deutsche Bank. So, their hesitance then reflected back on the market, so they kind of shared a few more years. And that's a process of the actual board members, and their openness or maturity and how long he still has a contract so that he still sees the benefits. The older the board member is, the less open he would be to*

support something like tokenization. It is an intracompany setting that needs to be right to grow.

- Katharina Gehra, Immutable Insight

That being said, it would be reasonable to note that age is not the only factor determining companies' openness to new technologies. As she mentions, the intracompany settings need to be suitable to ensure the company's growth in the industry, and the biggest banks and financial institutions should not be solely responsible for innovation on these solutions; it needs to be a collaborative effort involving all parties in the financial system.

To drive adaptation, central banks and policymakers may need to take the lead in piloting projects, building industry expertise, and helping the institutional transition. The financial industry in the United States is currently moving toward T+1 settlement, and there have been discussions on whether it is a good idea to move toward T+0 in the near future. The Securities Industry and Financial Markets Association (SIFMA) has published a report on whether the benefits outweigh the risks of implementing T+0. The report concluded that the high cost of implementing T+0 and the potential for backoffice mistakes and failed trades make T+0 undesirable (Bentsen, 2022). The report does not look at tokenization and smart contracts or the possibility of using wCBDC for settling transactions. It might change the outlook on moving towards a T+0 standard if implemented correctly.

8.5 New Risks Introduced

While introducing distributed ledger technologies and smart contracts offers efficiency gains for securities settlement, the new technology might introduce unknown risks, even though one of the main selling points is less risk during the settlements. The traditional bond market has existed for multiple decades. However, the digital and tokenized bond markets are new and barely tested, leading to unique risk factors to consider. The implementation of smart contracts can lead to smart contract risk. The design itself can contain bugs, and its creator can have trouble correcting them due to the immutability of the blockchain (Moody´s Investors Service, 2023). If the smart contract contains errors, the delivery versus payment process might cause the property transfer to fail and cause delays, making the new system slower than the old.

Accountability is also a potential issue with smart contracts, automated processes, and many parties are involved. This might pose a problem in determining who is liable if errors occur.

Clear accountability frameworks and resolution mechanisms must be in place to ensure fair and correct outcomes.

Multiple small-scale pilot projects have tested this technology and proved its capabilities. However, testing has yet to confirm that the technology will work on a full-scale adoption, and scalability issues may occur along the way. Full implementation could lead to technological and operational risks multiplying and not being as successful as the small-scale pilots.

9. Conclusion

As the potential of using distributed ledger technology (DLT) platforms and tokenizing assets emerges throughout the global economy, more and more central banks and financial institutions are looking to utilize the technology's benefits. The need for more efficient systems of wholesale settlement, custody, and risk reduction throughout the value chain of asset trading leads the way for new emerging technologies. Through an extensive literature review and expert interviews, we identified several benefits and challenges associated with implementing tokenization and DLT into the bond markets and value chain**.** We found that the tokenization of bonds in combination with a DLT-based wholesale CBDC will bring beneficial efficiency gains to the market. It will reduce the settlement time safely and reliably due to consensus mechanisms, as well as improve the trust in DLT among market participants through a potential release of a DLT-based wholesale CBDC. However, there are also substantial hurdles like interoperability, trust, and cost of implementation before full adoption can be achieved.

One of the main benefits of tokenizing bonds is enabling atomic settlement, reducing settlement time from T+2. By representing bonds as digital tokens on a distributed ledger, settlement can happen instantly through an atomic swap with a tokenized cash leg like wholesale CBDC. This reduces counterparty risk during the settlement period. The atomic settlement nature of a DLT-based wholesale CBDC could solve frictions and delays in the settlement. However, our findings show that moving from T+2 to an atomic settlement with a wholesale CBDC requires significant investment in transition systems and developing new institutional processes. These changes will demand investments in both time and money and coordination between different stakeholders.

Several projects in collaboration with BIS have proven the small-scale feasibility of the technology. However, the lack of real-world testing at a substantial scale has created uncertainty around the implications for technological and operational risks. Code errors in smart contracts or failed trade executions due to system design flaws could hinder the optimal efficiency goals. The frameworks and regulations for automated processes using DLT and tokenization are being introduced through MiCA and the Pilot Regime. However, they require further development to address all possible risks and challenges.

Designing interoperable solutions between diverse DLT platforms and legacy systems remains a key challenge. Individual central banks may develop unique technical approaches for a

potential wholesale CBDC. Meanwhile, private institutions may use token standards and distributed ledger technologies different from central banks. Solutions must be designed for compatibility to avoid fragmentation, and if not, the solution may introduce a risk of reinstating the siloed structure that DLT platforms aim to prevent. As well as overcoming interoperability hurdles, the lack of common governance standards may result in distrust and lack of confidence in the new systems. The general misconception that blockchain technology is equivalent to speculative cryptocurrencies poses a threat to the development of the technology.

According to experts, DLT-Based wholesale CBDC and tokenization of bonds can lead to estimated cost reductions ranging on average from 24% to 43% in the value chain processes, as illustrated in Table 2 and Table 3 in Chapter 7, The estimated cost reduction originates mainly from streamlining issuance, removing clearing, automating custody and servicing functions, and utilizing the programmable nature of smart contracts. While the cost savings vary between the different categories throughout the value chain, the benefits of tokenizing the bonds are visible in all categories. These cost savings are subject to the assumption that payment in either a stablecoin, tokenized deposit, or wCBDC is functional and efficient. It also assumes that the interoperability between individual DLT platforms works and that the different market participants are ready for implementation. Some of these intermediaries may be reluctant to invest in the effort required to implement the technology. The reasons discussed in the thesis could be in relation to both the investment costs and the possible losses in revenue due to the reduced need for intermediaries in the automated market processes.

While tokenization and DLT-based wholesale CBDC can theoretically introduce substantial efficiency gains and cost savings, transforming the traditional bond market infrastructure involves overcoming regulatory, technical, and coordination challenges. Regulators and industry leaders must collaborate on pilots modeling real-world conditions to determine full feasibility. If implemented properly, these technologies can reduce settlement times, costs, and risks, eventually transforming current bond markets. However, the path to broad adoption remains complex and uncertain.

9.1 Weaknesses of thesis

We want to acknowledge several weaknesses in our study about how CBDC and tokenization could help make the traditional bond market more efficient. As this thesis is primarily based

on existing literature and in-depth interviews, there are some limitations. Central bank digital currency and tokenization are still niche topics. Therefore, limited available academic research can challenge drawing a definitive conclusion. Additionally, a lack of consensus and disagreements between our selection of experts could impact the findings. There is also a risk of selection bias between the interview objects as the experts may have certain biases towards CBDC and tokenization. We´ve tried to eliminate this by interviewing individuals with different backgrounds and stances toward the topic, but there will always be a possibility for biases in the selection.

A qualitative study has limitations itself. While a qualitative study provides in-depth insight into the topic, it will not offer measurable estimations, which may lead to subjective interpretations. We have tried to eliminate this weakness to the best extent by implementing a small case study, where we try to quantify cost savings in tokenized bond issuance. However, with limited access to data, we had to rely on various reports. Lastly, our limited knowledge of computer science poses a weakness, as we may not fully understand the technical features of the technology behind tokenization and distributed ledger technology.

9.2 Future Research

Many questions remain unsolved and not considered in this thesis, as blockchain, DLT, and tokenization innovations are still in the early conceptual phase. In this short section, we will highlight some potential future research topics that could be interesting to explore further.

Qualitative data from real-world implementations will enable further investigating and analyzing the real effects of utilizing tokenization and DLT when accessible. It could be used to explore the cost savings and efficiency gains further. The technology may also improve energy efficiency in the banking and financial sectors, as proof of stake consensus mechanism is highly energy efficient.

Evaluating security risks and smart contract vulnerabilities will be important as different projects scale, and the adoption of the technology increases. Potential threats needs to be considered. Looking further into the aspects of the MiCA framework and the Pilot Regime's outcome could be interesting. It may increase the security of tokenizing assets and DLT infrastructures, and it could enable the emergence of stablecoins in Europe that have the potential to outperform the implementation of CBDCs.

Tokenization across different markets are beneficial to scope further. For instance, one can examine tokenization of stocks, where fractioning ownership of companies on and off exchanges could be one of the main benefits. This could improve liquidity, accessibility, and transparency, enabling shareholders to trade their stocks 24/7 rather than be restricted to the opening hours of the stock exchanges. One could also do the same for real estate and other illiquid assets and see how they may improve. It is also necessary to outline and consider the new risks when introducing the technology. Exploration of Security Token Offerings, in addition to DLT and tokenization in crowdfunding, could be an interesting research topic when the token economy develops further. This was originally topics we also wanted to explore, but after some interviews, we chose to focus on bond markets.

The token economy involving tokenized assets, DLT-based wholesale CBDC, stablecoins, tokenized deposits, and other use cases for DLT infrastructures is still in the early phases. Therefore, there is a substantial potential for further research and exploration.

References

Antonopoulos, A. M. (2017). Keys, Addresses. In *Mastering Bitcoin* (Vol. 2). O'Reilly Media, Inc.

Australian Bond Exchange. (2023). *Corporate and Government bonds*. Retrieved December 11, 2023, from bondexchange: https://www.bondexchange.com.au/corporate-vs-government-bonds/

Banerjee, A. (2022, September 01). *Everything You Need To Know About Consortium Blockchain*. Retrieved December 05, 2023, from Blockchain Counsil: https://www.blockchain-council.org/blockchain/everything-you-need-to-know-about-consortium-blockchain/

Banerjee, A., Bode, I. D., Vergnes, M. d., & Higginson, M. (2023, August 15). *McKinsey*. Retrieved October 15, 2023, from Tokenization: A digital-asset déjà vu: https://www.mckinsey.com/industries/financial-services/our-insights/tokenization-a-digital-asset-deja-vu#/

Bank of International Settlement Innovation Hub. (2020). *Project Helvetia, Settling tokenised assets in central bank money.* BIS Innovation Hub; Swiss National Bank; SIX.

Bank of International Settlement. (2023). *Project Icebreaker: Breaking new paths in cross-border retail CBDC payments.* Bank of International Settlement Innovation Hub.

Bank of International Settlements. (2021). *Central bank digital currencies: financial stability implications.* Bank of International Settlements.

Bankenes Sikringsfond. (2023). *Bankenes Sikringsfond*. Retrieved December 12, 2023, from How is the guarantee financed?: https://www.bankenessikringsfond.no/about-the-guarantee/how-is-the-guarantee-financed/

Beau, D. (2023, October 03). *Unveiling the potential of wholesale CBDC: What insights and prospects?* Retrieved November 27, 2023, from Banque de France: https://www.banque-france.fr/en/governors-interventions/unveiling-potential-wholesale-cbdc-what-insights-and-prospects

Bentsen, K. (2022, February 02). *T+0? More Risk, Fewer Benefits*. Retrieved December 03, 2023, from SIFMA: https://www.sifma.org/resources/news/t0-more-risk-fewer-benefits/

BIS Innovation Hub. (2020, December 03). *Project Helvetia: Delivery versus payment with w-CBDC (PoC1)*. Retrieved November 27, 2023, from Youtube: https://www.youtube.com/watch?v=XNlbnHh_DgQ&ab_channel=BankforInternationalSettlements

BIS, SIX group, SND. (2022). *Project Helvetia Phase II: Settling tokenised assets in wholesale CBDC.* BIS Innovation Hub.

BNP Paribas. (2023, June 08). *T+1 settlement: Are you ready?* Retrieved September 06, 2023, from BNP Paribas: https://securities.cib.bnpparibas/t1-settlement-ready/

Cashlink. (2020, October 01). *Cost Disruption in the Issuance Market*. Retrieved September 15, 2023, from Cashlink: https://cashlink.de/en/cost-disruption/

CBDC Tracker. (2023, November). *Today´s Central Bank Digital Currencies Status*. Retrieved November 15, 2023, from CBDC Tracker: https://cbdctracker.org/

Çelik, S. G., & Isaksson, M. (2020). *Corporate Bond Market Trends, Emerging Risks and Monetary Policy.* Paris: OECD Capital Market Series.

CFI Team. (2022). *What Happened to Terra?* (A. Loo, Editor) Retrieved November 02, 2023, from Corporate Finance Institute: https://corporatefinanceinstitute.com/resources/cryptocurrency/what-happened-to-terra/

CFI Team. (Unkown Date). *Corporate Finance Institute*. Retrieved December 02, 2023, from Swift: https://corporatefinanceinstitute.com/resources/foreign-exchange/swift/#:~:text=Today%2C%20SWIFT%20covers%2011%2C000%20banks,passing%20through%20the%20system%20daily.

Chainlink. (2023, November 29). *What Are Smart Contracts and How Do They Work?* Retrieved December 02, 2023, from Chainlink: https://chain.link/education/smart-contracts

Dawson, R., & Baxter, M. (2019, August 29). *ANNOUNCING HYPERLEDGER BESU*. Retrieved December 13, 2023, from Hyperledger: https://www.hyperledger.org/blog/2019/08/29/announcing-hyperledger-besu

De Nederlandsche Bank. (2020). *Central Bank Digital Currency - Objectives, preconditions and design choices* . De Nederlandsche Bank.

Deloitte. (2019). *The evolution of a core financial service Custodian & Depositary Banks.* Luxembourg: Deloitte.

Deutsche Bundesbank. (2022). *Cross-border interoperability of central bank digital currency.* Deutsche Bundesbank.

Downes, P., & Vaez-Zadeh. (1991). *The Evolving Role of Central Banks.* Washington D.C.: Internatinal Monetary Fund.

Dubey, A. (2023, June 28). *Tokenized Deposits: Unlocking New Possibilities in Finance*. Retrieved November 29, 2023, from Medium:

https://medium.com/coinmonks/tokenized-deposits-unlocking-new-possibilities-in-finance-a5b5e5b683ba

Dutch Authority for the Financial Markets. (2023). *DLT Pilot Regime*. Retrieved December 12, 2023, from afm.nl: https://www.afm.nl/en/sector/themas/digitalisering/dlt-pilot-regime#:~:text=The%20DLT%20Pilot%20Regime%20introduces,under%20the%20DLT%20Pilot%20Regime.

ECB. (2023, March 21). *Successful launch of new T2 wholesale payment system*. Retrieved September 13, 2023, from European Central Bank: https://www.ecb.europa.eu/press/pr/date/2023/html/ecb.pr230321~f5c7bddf6d.en.html

Emerging Markets Group. (2005). *Bond Issuance Tool Kit for Emerging Market Corporate Issuers.* Emerging Markets Group.

Ethereum. (2023, May 31). *ERC-20 TOKEN STANDARD*. Retrieved November 07, 2023, from ethereum.org: https://ethereum.org/en/developers/docs/standards/tokens/erc-20/

Ethereum. (2023, September 26). *PROOF-OF-STAKE (POS)*. Retrieved November 07, 2023, from ethereum.org: https://ethereum.org/en/developers/docs/consensus-mechanisms/pos/

European Central Bank. (2017, June 20). *What is money?* Retrieved September 05, 2023, from European Central Bank: https://www.ecb.europa.eu/ecb/educational/explainers/tell-me-more/html/what_is_money.en.html

European Central Bank. (2022). *Facts and figures*. Retrieved September 05, 2023, from European Central Bank: https://www.ecb.europa.eu/paym/target/target2/facts/html/index.en.html

European Central Bank. (2022). *Study on the payment attitudes of consumers in the euro area (SPACE) – 2022*. Retrieved September 05, 2023, from European Central Bank: https://www.ecb.europa.eu/stats/ecb_surveys/space/html/ecb.spacereport202212~783ffdf46e.en.html

European Central Bank. (2023, March 21). *Successful launch of new T2 wholesale payment system*. Retrieved November 13, 2023, from European Central Bank: https://www.ecb.europa.eu/press/pr/date/2023/html/ecb.pr230321~f5c7bddf6d.en.html

European Central Bank. (2023). *What is TARGET2-Securities (T2S)?* Retrieved December 11, 2023, from European Central Bank: https://www.ecb.europa.eu/paym/target/t2s/html/index.en.html

European Union. (2023). *REGULATION (EU) 2023/1114 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 31 May 2023 on markets in crypto-assets, and amending Regulations (EU) No 1093/2010 and (EU) No 1095/2010 and Directives 2013/36/EU and (EU) 2019/1937.* Official Journal of the European Union.

EY Norge. (2020, September 14). *Digitale sentralbankpenger – dette må du vite*. Retrieved November 15, 2023, from EY: https://www.ey.com/no_no/blockchain/digitale-sentralbankpenger

Fariña, P. M. (2019, March 28). *Step-by-step guide to issuing a bond*. Retrieved November 16, 2023, from Banco Bilbao Vizcaya Argentaria, BBVA: https://www.bbva.com/en/step-by-step-guide-to-issuing-a-bond/

Fiona. (2020, October 02). *Finoa*. Retrieved October 12, 2023, from Cost disruption in the issuance market: The case for tokenization: https://www.finoa.io/blog/cost-savings-tokenization/

Frankenfield, J. (2023, February 17). *What Are Consensus Mechanisms in Blockchain and Cryptocurrency?* Retrieved November 02, 2023, from Investopedia: https://www.investopedia.com/terms/c/consensus-mechanism-cryptocurrency.asp

Friewald, N., Jankowitsch, R., & Subrahmamyam, M. (2013). Illiquidity or credit deterioration: A study of liquidity in the US corporate bond market during financial crises. *Journal of Financial Economics, 105*(1), 18-36.

Ghosh, S. (2023, October 26). *JPMorgan Says JPM Coin Now Handles $1 Billion Transactions Daily*. Retrieved November 29, 2023, from Bloomberg: https://www.bloomberg.com/news/articles/2023-10-26/jpmorgan-says-jpm-coin-now-handles-1-billion-transactions-daily

Gysegem, F. V., & Patoul, K. D. (2021). *The Tokenization of the Economy and its Impact on Capital Markets and Banks.* Munich : Roland Berger.

Häring, W., Wöckener, K., & Freudenberger, D. C. (2023, July 04). *MiCA Regulation: New regulatory framework for Crypto-Assets Issuers and Crypto-Asset Services Providers in the EEA*. Retrieved November 03, 2023, from White & Case: https://www.whitecase.com/insight-alert/mica-regulation-new-regulatory-framework-crypto-assets-issuers-and-crypto-asset

Hashemi Joo, M., Nishikawa, Y., & Dandapani, K. (2020). Cryptocurrency, a successful application of blockchain technology. *Blockchain Applications in Finance, 46*(6), 715-733.

Hebert, J., Moshammer, E., & Barth, H. (2023). *Wholesale central bank digital currency – the safe way to debt capital market efficiency.* European Stability Mechanism.

Helm, S., & Katz, E. (2023, September 06). *Custody of stablecoin reserves under MiCA* Retrived December 17, 2023, The Banker: https://www.thebanker.com/Custody-of-stablecoin-reserves-under-MiCA-1693986077

Hennerich, H. (2023, May 17). *What Makes a Market an Oligopoly?* Retrieved December 02, 2023, from Federal Reserve Bank of ST. Louis: https://www.stlouisfed.org/open-vault/2023/may/what-makes-a-market-an-oligopoly

Hennink, M., & Kaiser, B. (2021, November 02). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine, 292*.

IBM. (Unkown date). *What are smart contracts on blockchain?* Retrieved November 02, 2023, from IBM: https://www.ibm.com/topics/smart-contracts

ICMA. (2020, August). *Bond Market Size - Global*. Retrieved November 08, 2023, from ICMA Group: https://www.icmagroup.org/market-practice-and-regulatory-policy/secondary-markets/bond-market-size/

International Finance. (2021, January 21). *The evolution of blockchain in bond issuance*. Retrieved November 15, 2023, from International Finance: https://internationalfinance.com/magazine/technology-magazine/the-evolution-of-blockchain-in-bond-issuance/#:~:text=Typically%2C%20the%20process%20comprises%20two,investor%20in%20terms%20of%20securities.

Jha, S. (2023, Mai 31). *The Complete Guide for Types of Blockchain!* Retrieved November 06, 2023, from Simplilearn: https://www.simplilearn.com/tutorials/blockchain-tutorial/types-of-blockchain

Kagan, J. (2022, May 25). *Settlement Risk: Definition, 2 Main Types, and How To Reduce It*. Retrieved December 03, 2023, from Investopedia: https://www.investopedia.com/terms/s/settlementrisk.asp

Karam, A. A. (2023, August 17). *Central Bank Digital Currency (CBDC) and blockchain enable the future of payments*. Retrieved September 13, 2023, from IBM: https://www.ibm.com/blog/central-bank-digital-currency-cbdc-and-blockchain-enable-the-future-of-payments/

Kobayakawa, S., Kawada, Y., Kobayashi, A., Bullmann, D., Bachmann, A., Humbert, C., . . . Pinna, A. (2018). *Securities settlement systems: delivery-versus-payment in a distributed ledger enviorment.* European Central Bank & Bank of Japan.

KPMG. (2022). *Stable (or not-so-stable) coins*. Retrieved September 12, 2023, from KPMG: https://kpmg.com/xx/en/home/insights/2022/06/stable-or-not-so-stable-coins.html

Kumar, S., Suresh, R., Liu, D., Kronfellner, B., & Kaul, A. (2022). *Relevance of on-chain asset tokenization in 'crypto winter'.* BCG & ADDX.

Legal Nodes Team. (2023, July 27). *The EU Markets in Crypto-Assets (MiCA) Regulation Explained*. Retrieved November 10, 2023, from Legal Nodes: https://legalnodes.com/article/mica-regulation-explained#:~:text=The%20key%20objectives%20of%20MiCA,service%20providers%20and%20token%20issuers

Liao, G. Y., & Caramichael, J. (2022). *Stablecoins: Growth Potential and Impact on Banking.* Washington: International Finance Discussion Papers.

Manconi, A., Neretina, E., & Renneboog, L. (2019). *Underwriter Competition and Bargaining Power in the Corporate Bond Market.* European Corporate Governance Institute, ECGI.

Mandeng, O. J. (2021, January 15). *CBDC for retail, wholesale and international Payments*. Retrieved November 12, 2023, from Accenture: https://bankingblog.accenture.com/cbdc-retail-wholesale-international-payments

McKinsey. (2023, March 01). *What is central bank digital currency (CBDC)?* Retrieved September 12, 2023, from McKinsey & Company: https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-central-bank-digital-currency-cbdc#/

McNew, S. S., Gosalia, V., & Rega, A. (2023). *Myth Busting: 5 Common Misconceptions in Blockchain and Digital Assets*. Retrieved December 05, 2023, from FTI Consulting: https://www.ftitechnology.com/resources/blog/myth-busting-5-common-misconceptions-in-blockchain-and-digital-assets

Meholm, L. (2023, September 28). Interview, CBDC and Tokenization of Bonds. (U. M. Martin, & A. R. Chris, Interviewers)

Miah, M. (2020). *Blockchain Technology in Peer-to-Peer eLearning: Opportunities and Challenges.* Tennessee State University, Deapartment of Business Information Systems. Tennessee: Information Systems & Computing Academic Professionals (ISCAP).

Moody´s Investors Service. (2023). *Digital bonds' features could transform debt markets over time.* Moody´s Investors Service.

Muir, M. (2023, July 20). *Jamaica, we have a CBDC.* Retrieved November 21, 2023, from Financial Times: https://www.ft.com/content/91ac9f03-1ff8-47c9-bd0f-64449e2159d8

Murphy, C. B. (2023, April 24). *Investopedia*. Retrieved from Over-the-Counter (OTC): Trading and Security Types: https://www.investopedia.com/terms/o/otc.asp

Nevil, S. (2023, May 27). *What Is Proof of Work (PoW) in Blockchain?* Retrieved November 07, 2023, from Investopedia: https://www.investopedia.com/terms/p/proof-work.asp#citation-1

New Constructs. (2023). *Our Credit Ratings Methodology*. Retrieved December 12, 2023, from New Constructs: https://www.newconstructs.com/credit-rating-methodology/

Norges Bank. (2018). *Central bank digital currencies: First report of working group.* Norges Bank.

Norges Bank. (2019). *Central bank digital currencies: Second report of working group.* Norges Bank.

Norges Bank. (2021). *Central bank digital currencies: Third report of working group.* Norges Bank.

Norges Bank. (2022, September 28). *Norges Bank*. Retrieved December 11, 2023, from Project Icebreaker: https://www.norges-bank.no/en/topics/financial-stability/cbdc/nyheter-om-dsp/project-icebreaker/

Norges Bank. (2022). *Idémyldring om digitale sentralbankpenger*. Retrieved from Vimeo: https://vimeo.com/774427792/850975d515

Norges Bank. (2023, September 13). *What is central bank digital currency?* Retrieved November 12, 2023, from Norges Bank: https://www.norges-bank.no/en/topics/financial-stability/cbdc/what-is-central-bank-digital-currencies/

Norges Bank. (2023, September 14). *Korleis jobbar Noregs Bank med DSP?* Retrieved December 13, 2023, from Norges Bank: https://www.norges-bank.no/tema/finansiell-stabilitet/digitale-sentralbankpenger/hvordan-jobber-norges-bank-med-dsp/

Ondo Finance. (2023, January 10). *Ondo Launches Tokenized US Treasuries and Bonds, Targeting $100 Billion Stablecoin Market*. Retrieved December 01, 2023, from Ondo Finance: https://www.prnewswire.com/news-releases/ondo-launches-tokenized-us-treasuries-and-bonds-targeting-100-billion-stablecoin-market-301717327.html

Ondo Finance. (2023). *Trust & Transparency*. Retrieved December 04, 2023, from Ondo Finance: https://docs.ondo.finance/general-access-products/usdy/faq/trust-and-transparency

Panetta, F. (2022, September 26). *Demystifying wholesale central bank digital currency*. Retrieved November 14, 2023, from European Central Bank: https://www.ecb.europa.eu/press/key/date/2022/html/ecb.sp220926~5f9b85685a.en.html

PIMCO. (Unknown Date). *Bonds*. Retrieved November 21, 2023, from PIMCO: https://europe.pimco.com/en-eu/resources/education/everything-you-need-to-know-about-bonds#/:~:text=Potential%20hedge%20against%20an%20economic,income%20that%20doesn't%20change.

Pratap, Z. (2022, November 09). *Chainlink*. Retrieved December 11, 2023, from Upgradable Smart Contracts: What They Are and How To Deploy Your Own: https://blog.chain.link/upgradable-smart-contracts/

Ramachandran, S., Kok, S., Lucas, S., Ananias, A., & Jenner, M. (2022). *The Future of Distributed Ledger Technology in Capital Markets.* Boston Consulting Group & J.P. Morgan.

Richards, T., Thompson, C., & Dark, C. (2020). *Retail Central Bank Digital Currency: Design Considerations, Rationales and implications.* Reserve Bank of Australia.

Roland Berger. (2023). *Tokenization of Real-World Assets: Unlocking a New Era of Ownership, Trading, and Investmen.* Dubai: Roland Berger.

Rosen, A. (2023, September 23). *The Worst Bond Year Ever Was 2022 – What Does That Mean For You?* Retrieved December 03, 2023, from Forbes: https://www.forbes.com/sites/andrewrosen/2023/02/09/the-worst-bond-year-ever-was-2022--what-does-that-mean-for-you/?sh=6040f8c13ae8#:~:text=According%20to%20the%20Barclay%27s%20U.S.,historically%20bad%20–%20down%2013%25.

Santander. (2023, January 02). *What are central banks and why are they so important?* Retrieved September 10, 2023, from Santander: https://www.santander.com/en/stories/what-is-a-central-bank

Sarmah, S. S. (2018, August 08). Understanding Blockchain Technology. *Computer Science & Engineering: An International Journal*, 23-24.

Saunders, M., Lewis, P., & Thornhill, A. (2012). *Reasearch Methods For Business Students.* England: Pearson Education Limited.

Schmidt, M. (2023, Mai 22). *The Benefits of a Bond Portfolio*. Retrieved December 12, 2023, from Investopedia: https://www.investopedia.com/articles/bonds/08/bond-portfolio-made-easy.asp#:~:text=Bonds%20are%20a%20vital%20component,stock%20portfolios%20and%20reduce%20losses.

SEC. (2013, June 04). *What Are Corporate Bonds?* Retrieved December 12, 2023, from Investor.gov: https://www.investor.gov/introduction-investing/general-resources/news-alerts/alerts-bulletins/investor-bulletins/what-are

Securties and Exchange Commission. (2004, May 21). *About Settling Trades In Three Days: Introducing T+3*. Retrieved September 05, 2023, from Securties and Exchange Commission: https://www.sec.gov/about/reports-publications/investor-publications/about-settling-trades-in-three-days-introducing-t-3

Six Group. (2023, November 02). *SIX collaborates with the Swiss National Bank to pilot wholesale CBDC issuance in Switzerland*. Retrieved December 06, 2023, from Six Group: https://www.six-group.com/en/newsroom/media-releases/2023/20231102-six-sdx-snb-helvetia-lll.html

SWIFT. (2023, November 30). *Instant cross-border payments usher in a new phase of global financial interoperability*. Retrieved December 06, 2023, from Swift: https://www.swift.com/news-events/news/instant-cross-border-payments-usher-new-phase-global-financial-interoperability

Tani, S. (2023, March 24). *US experiences biggest bank failures since global financial crisis*. Retrieved November 30, 2023, from Fiancial Times: https://www.ft.com/content/d14937f3-efe4-4f84-9b67-c520346d2248

Tewes, M., Bauer, M., & Holz, G. (2023). *Security Tokenization; How to unlock hidden value by moving stocks, bonds, and funds on the blockchain.* Porsche Consulting.

European Central Bank. (2019). *Exploring anonymity in central bank digital currencies.* Eurochain.

The European Parlament & Concile of the European Union. (2022, June 02). REGULATION (EU) 2022/858 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2022 on a pilot regime for market infrastructures based on distributed ledger technology, and amending Regulations (EU) No 600/2014 and (EU) No 909/2014 and Directive 2014/6. *REGULATIONS*, 151/1 - 151/33.

The European Union. (2019, June 20). *GUIDELINE (EU) 2019/1007 OF THE EUROPEAN CENTRAL BANK of 7 June 2019 amending Guideline ECB/2012/13 on TARGET2-Securities (ECB/2019/16)*. Retrieved December 11, 2023, from EUR-Lex: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019O0016

Trading Economics. (Unknown Date). *Credit Rating*. Retrieved November 21, 2023, from Trading Economics: https://tradingeconomics.com/country-list/rating

Ugarte, J. R. (2018). *Distributed ledger technology (DLT): introduction.* Banco de España.

Valverde, S. C., Solas, P. J., & Fernández, F. R. (2021). Non-pricing drivers of underwriters' market shares in corporate bond markets. *International Review of Economics and Finance*, 672.

Wind, P. (2023, December 05). *Coincodex*. Retrieved December 11, 2023, from Why Did Luna Crash 99.99%? Here's What Happened to Terra Luna Classic: https://coincodex.com/article/22749/what-happened-to-luna/

Appendix A – Interview Request

Interview Request

Master Thesis Norwegian School of Economics

Topic: CBDC´s and tokenization´s effects on bonds and crowdfunding

We are two students from the Norwegian School of Economics, currently working on our master's thesis focused on Central Bank Digital Currencies (CBDC) and Tokenization. Our research aims to explore the potential of CBDC in connection with tokenization to enhance the efficiency and cost-effectiveness of traditional bond- and crowdfunding markets.

Considering your expertise and the notable role of your company/organization in this sector, we are keen on discussing your perspectives on this topic. Would you be open to participating in an interview with us discussing the following topics?

Topics:
Perspectives on CBDC and tokenization.

Efficiency and cost-effectiveness:
- Challenges in traditional securities markets.
- Potential for improvement in efficiency and cost savings.
- Could CBDC and tokenization address this.

Instant settlement with CBDC and tokenized securities:
- Use in issuance of bonds and managing crowdfunding.
- Thoughts on STO and IEO for raising funds.
- Benefits of immediate settlement with tokenization and CBDC.
- Challenges and advantages.

Future outlooks:
- Scalability of tokenization and CBDC.
- Impact on financial markets.

If you agree to this interview:
- We request your permission to acknowledge your contribution in our study. Any quotations will be shared with you for verification before being included in our publication.
- If you prefer anonymity, we will ensure all personal details are kept confidential. Any collected data will be securely stored and deleted upon the conclusion of our project.
- Participation is voluntary, and you can opt-out at any moment, at which point all related data will be immediately deleted.

Interview details:
The interview will be for approximately 45-60 minutes. Can be conducted face-to-face, via Teams, or phone, based on your convenience. The session will be audio-recorded for accurate transcription and citation. The recording will be deleted post-project to uphold your privacy. Your insights will be invaluable to our research, and we genuinely hope you'll consider our request. If you have any questions or need further details about our study, please don't hesitate to reach out.

We eagerly await your response. Below are our contact details for your reference.

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Appendix B – Interview Guide

Interview Guide:

CBDC, tokenization, and the future of bond and crowdfunding markets

Introduction

- What are your field of expertise and the primary services provided by your company/entity?

- How do you/your company address and incorporate emerging technologies? If related to blockchain, tokenization, or CBDC, please describe your familiarity or involvement.
    - Innovative solutions, strategy, target areas.

Central Bank Digital Currencies (CBDC)

- How do you view the potential of CBDCs in reshaping the markets for financial and illiquid assets?
    - Pros and cons, accessibility, speed, costs, regulatory aspects, MiCA, GDPR, programmability of CBDC, smart contracts.

- How might CBDCs affect banking practices and the financial ecosystem regarding investor transactions, Payment versus payment, and Delivery versus payment?
    - Threats, opportunities, current VS future systems, settlement, and custody.

Tokenization

- How do you see tokenization influencing how assets, particularly bonds, are issued, traded, and managed in both primary and secondary markets?
    - Liquidity, transparency, global reach, efficiency, cost saving.

- What are the potential challenges related to the tokenization of assets?
    - Vulnerabilities, management of cryptographic keys, consensus mechanisms (proof of work, proof of stake), immutability, fraud, and security.

Interplay of CBDC and Tokenization

- What advantages do you see in the use of a DLT-based/compatible CBDC in Security Token Offerings and or Initial Exchange Offerings (STO, IEO) (alternatives to crowdfunding)?

- How can the interplay of CBDC and tokenization bring greater efficiency and transform bonds, crowdfunding, joint venture markets, and other financial and illiquid assets?
    - Synergies, challenges in integration, compatibility between tokens and CBDC, liquidity, accessibility, reduction of intermediaries, cross-border transactions, and settlement efficiency.

- Can tokenization provide more control to investors and contributors in bonds and crowdfunding markets?
    - Ownership rights, fractional ownership, real-time tracking and access, primary and secondary markets.

- What, in your opinion, are the most cost-saving aspects of using CBDC and tokenized assets?
    - Transaction speed, custody, intermediaries, settlement, and clearing.

Prospects & reflections

- What hurdles must be addressed before mass adoption of CBDC and tokenization begins?
    - Technological barriers, market acceptance, trust in society, fear of fraud (connection to the speculative nature of crypto), regulations, outperformance of traditional technology, immutability.

- What is the most critical aspect of CBDC and tokenization when integrating it into bonds, crowdfunding, and financial and illiquid assets?

- How do you see the future of these markets, with the potential slow and steady adoption of CBDC and tokenization?

- Do you have any thoughts on the subjects that we did not discuss during this interview?

Appendix C – List of interview objects

List of interview objects						
-	Name	Company	Title	Sector	Country	LinkedIn
1	Alexander Rieger	University of Arkansas	Assistant Professor	Academica	United States	linkedin.com/in/alexanderrieger/
2	Alexandra Elisa Thomé	Deutche Bundesbank	Senior Expert Digital Euro	Central Bank	Germany	linkedin.com/in/alexfortmuller/
3	Christoph Gschnaidt-ner	Technische Universität München	Researcher	Academica	Germany	linkedin.com/in/christoph-gschnaidtner/
4	Johannes Sedlmeir	SnT - University of Luxembourg	Post-doctoral Researcher	Academica	Luxemburg	linkedin.com/in/johannes-sedlmeir/
5	Jon Ramvi	Brønnøysun-dregistrene / Oslo kommune / Norges bank	Web3 - Consultant	Fintech	Norway	linkedin.com/in/jonramvi/
6	Katharina Gehra	Immutable Insight	CEO & Co-Founder	Fintech	Germany	linkedin.com/in/katharinagehra/
7	Lasse Meholm	FinansIT	CEO / Head Consultant for Norges Bank	Central Bank	Norway	linkedin.com/in/lasse-meholm-92855a2/
8	Nadia Pocher	SnT - University of Luxembourg	Post-doctoral Researcher	Academica / Legal	Luxemburg	linkedin.com/in/nadia-pocher-02962a12a/?originalSubdomain=lu
9	Ole Einar Stokstad	Norselab	Senior Portfolio Manager	Finance	Norway	linkedin.com/in/ole-einar-stokstad-42865a151/
10	Peder Østbye	Norges Bank	Director of Analysis	Central Bank	Norway	linkedin.com/in/peder-%C3%B8stbye-7155183/