

Evaluation of Central Bank-issued Digital Currency (CBDC) Implementation Designs using Transaction Cost Economics Perspective

Master's Thesis



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Master Management of Technology

Faculty of Technology, Policy, and Management



Delft University of Technology

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Master thesis submitted to Delft University of Technology
in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in Management of Technology

Faculty of Technology, Policy and Management

by

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To be defended in public on October 29th, 2018

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Preface

This master thesis is a conclusion of my two-years education in Management of Technology program of the Faculty of Technology, Policy, and Management in TU Delft. This thesis report represents all the hard works I have done during the last eight months, as well as all the sets of knowledge I have gained during the last two years, especially those that are related to Economics & Finance specialization.

First of all, I would like to thank Prof. dr. C. P. (Cees) van Beers as my first supervisor that gave me opportunities to work on this project. Although I took Economics & Finance specialization in this program, I have never heard about a ‘creature’ called central bank-issued digital currency (CBDC). However, he accepted me as one of his master thesis students. To me, he was the most patient professor I have ever met. During the last eight months, together with Dr. Bram and Martijn, he helped me to shape and develop my research. Through the difficult times, he always said encouraging words and valuable feedbacks so that I could finally conclude this master thesis.

Second, I would like to thank Dr. ing. A. J. (Bram) Klievink as my second supervisor. During the research period, Dr. Bram has provided me useful feedbacks on my works, especially on the critical areas so that I could finally produce a high-quality thesis report.

Third, I would like to thank Martijn van der Linden as my external and day-to-day supervisor. Martijn patiently taught me about the concept of money, provided me with abundant literature on CBDC and money and banking (thank you for introducing *The End of Banking* to me), and even accompanied me to conduct an interview session with one of the most respected experts in his field.

Fourth, I would like to express my deepest gratitude to my parents and friends that have provided unlimited support for me during my Master education, especially in difficult times. Whenever I thought I could not make it, they would give me their hands. Without their supports, I would not be able to achieve this far. Also, I would like to dedicate this work to Verawaty, who not only provided significant supports but also inspired me to finish this thesis report through the difficult times.

Lastly, I would like to give special thanks to LPDP scholarship (Indonesia Endowment Fund for Education) from the Ministry of Finance of Republic of Indonesia as my main sponsor to study in TU Delft.

Den Haag, October 2018

Ivo Bahar Nugroho

Executive Summary

The advancement in digital technology provides room for innovations in many sectors, including in the financial sector. The development of digital currencies is one example of digital advancements in this sector. As the name implies, digital currencies, in general, can be defined as the digital or electronic form of currency. Digital currencies can take many forms, and cryptocurrency is one of the most popular forms of digital currencies today. Bitcoin and other cryptocurrencies (or altcoins) have slowly been adopted around the world as a means of payment. However, Bitcoin and altcoins are not issued by the central banks or other central authorities, making it difficult to regulate. At the same time, in several countries, the use of cash is declining to a very low rate. In the case of Sweden, in 2016, its ratio of cash (notes and coins) in circulation outside banks to GDP was only 1.38%. As the response to these economic phenomena, central banks in some countries are investigating the possibility of introducing their own version of digital currency which is called central bank-issued digital currency or CBDC.

Although the idea of CBDC has been discussed for some years, there is no common consensus of its definition and design options. Several reasons may cause this. First, the concept of CBDC itself is not too clear; some people say that the central banks have issued CBDC in the form of central bank reserves (that is only accessible by the commercial banks), while the others say that CBDC should be distinguished from the central bank reserves. Second, the implementation of CBDC is highly influenced by the central banks' purposes of issuing CBDC and the economic conditions of their respective country or economic zone. Third, the ongoing discussions of CBDC issuance involve not only the central banks, but also the general public, thus there are a lot of perspectives on the best way to design and implement CBDC, and even on a bigger question: should CBDC be introduced?

The increasing interest in CBDC and the dynamics of the ongoing CBDC discussions motivated this research to contribute to the discussions, as well as to provide an understanding of CBDC to broader audiences. However, unlike the analysis of the central banks that are more focused on the impacts of CBDC on economic and financial aspects, especially on the monetary policy, payment system, and financial stability, this research evaluates the CBDC design options that are being discussed from the perspective of transaction costs. Transaction cost analysis helps the authorities to identify and evaluate the potential costs, efforts, or investments that need to be made by the impacted economic agents in relation to CBDC. In the end, it is expected that the transaction cost analysis can help to improve preliminary evaluations and screening across CBDC design options; enhance the effective design and implementation of CBDC to achieve the set objectives; and evaluate the implemented CBDC design in order to improve its effectiveness.

This research uses transaction cost economics (TCE) theory, which was developed by Oliver Williamson, the recipient of the 2009 Nobel Memorial Prize in Economic Science, as the main framework of the transaction cost analysis. TCE was built to explain the reasons of the existence of firms, i.e., to maximize profits (or to minimize transaction costs). Rejecting neoclassical economics assumptions, TCE sees the market as imperfect and inefficient because of the existence of transaction costs that can be characterized by three main transactional dimensions: uncertainty, transaction frequency, and asset specificity.

This research shows how to implement TCE framework to characterize transaction costs in several CBDC design options. In general, this research was conducted in four steps. The first three steps were achieved through in-depth semi-structured interview sessions with several experts from central banks, commercial bank, regulatory bodies, and NGOs in the European developed economies that were

followed by a two-cycle coding process to extract the main ideas and contexts of the interview sessions. The last step was done as a conclusion from the first three steps.

The first three steps were: 1) determining available CBDC design options; 2) identifying impacted economic agents in each CBDC design option; and 3) operationalizing the transactional dimensions of TCE (i.e., uncertainty, transaction frequency, and asset specificity) in the context of CBDC. Finally, the last step was characterizing and inferring the transaction costs for each CBDC design option based on the results of the previous steps.

The results of the interview sessions showed several findings. First, according to the experts, there are three main CBDC design options: Retail CBDC, Wholesale CBDC, and Full-reserve Depository Banks CBDC. Each design option has a unique combination of CBDC-related attributes, which are accessibility, anonymity, interest-bearing, primary money function, peer-to-peer transaction, distributed ledger technology (DLT) implementation, and deposit guarantee scheme (DGS) removal. Second, among the three transactional dimensions of TCE (uncertainty, transaction frequency, and asset specificity), the uncertainty aspect provides a significant contribution to overall transaction costs. Third, the central bank and commercial banks are the ones that bear most of the transaction costs, especially in Retail CBDC design option, while the households and non-financial institutions do not need to bear any transaction costs. However, the latter finding might not be generalizable, as it might not be the case that households and non-financial institutions do not need any efforts or make some investments to access CBDC; thus, further experimentations and evaluations are still required to confirm this specific finding.

By being the pioneer in implementing TCE framework in the context of CBDC, this research can be used by a broad range of audiences, especially by central banks and academics, as a starting point or a reference for future research related to the characterization of the transaction costs of CBDC. Other possibilities for future research include the quantification of the characterized transaction costs in each CBDC design option and the application of the methodology in this research in the developing economies.

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1 Chapter 1 – Introduction

This chapter provides the background and the problem that will be addressed in this research, including its scope, objectives, and main questions.

1.1 Background

1.1.1 The Rise of Digital Currencies

Advancement in digital technology allows new innovations in the financial sector to emerge and develop in the society. On one side, the innovations could bring benefits to society, but on the other side, they could potentially bring negative impacts to the society or even disrupt the stability of the financial system itself. The development of one form of digital currencies, which is called as cryptocurrency, such as Bitcoin and Ethereum, is one example of digital advancements in the financial sector.

Cryptocurrency is basically a digital asset used as a medium of exchange (Chohan, 2017) that is equipped with a cryptographic algorithm to secure or control the flow of transactions (in effort to prevent double-spending) and the issuance of new units (in effort to maintain its limited supply). The idea of cryptocurrency can be traced back to 1983 when David Chaum published a paper titled Blind Signatures for Untraceable Payments. In that paper, he raised a concern about the privacy issue of payment system where the identity of the payee and the information of the transaction can be obtained by a third party. Thus, he proposed an automated payment system with cryptography mechanism that prevents information theft by a third party while still allows the payee and payer to provide proof of payment or their identity “under exceptional circumstances” (Chaum, 1983, p. 199). He called the mechanism as blind signature cryptosystems that was basically an extension of the RSA algorithm (Griffith, 2014). Chaum then established a company called DigiCash in the Netherlands to develop and commercialize his idea in the form of eCash. However, the company went bankrupt in 1998 and eventually eCash and other idea of cryptocurrency “faded into the background” (Nian & Chuen, 2015, p. 9).

In 2008, a paper written by Satoshi Nakamoto¹ specifies the idea and underlying technology of a cryptocurrency called Bitcoin, including their solution to prevent double-spending using hash-based proof-of-work (Nakamoto, 2008). Bitcoin is implemented under open-source license and its network utilizes a form of distributed ledger technology called blockchain. Since its release, Bitcoin has been used for various transactions. As per 22 August 2018, Bitcoin network has processed on average 240,673 confirmed transactions per day². The popularity of Bitcoin and the understanding of the underlying technology of Bitcoin inspire other cryptocurrencies (referred to as alternative coins or alt coins (Nian & Chuen, 2015)), such as Ethereum, Dash, and Stellar, to appear³.

Nian & Chuen (2015) specifies several benefits and risks of cryptocurrencies, especially Bitcoin. Some of the offered benefits are: 1) the freedom of payments where the users can make and receive payments

¹ Satoshi Nakamoto is not a name of a person; it is a pseudonym used by an unknown entity (could be a person, a group of people, or an organization) who created Bitcoin network.

² Source: <https://www.blockchain.com/charts/n-transactions?daysAverageString=7×pan=all>, retrieved on 22 August 2018.

³ As per August 2018, there are 1,865 known cryptocurrencies circulated on the market (source: <https://coinmarketcap.com/all/views/all/>, retrieved on 22 August 2018).

“with little or no fees” (p. 22) due to the inexistence of third-party intermediaries and also “make fast cross-border transfers easily without paying expensive fees for remittances” (p.23); 2) minimum costs for merchants for accepting payments, thus allowing the merchants to accept micropayments “without a minimum transaction level” (p. 23); and 3) protection for the users where unethical merchants are unable to “slip in unwanted charges later” because transactions do not contain substantial personal information and can only be initiated by the users that have their own private keys. On the other hand, Bitcoin also has some risks, which are: 1) the volatility of its value that makes it “difficult to determine how good bitcoins are as a store of value” (p. 24); 2) the possibility of facilitating criminal activities due to its pseudo-anonymity nature, as well as money laundering and terrorists financing activities⁴; 3) the uncertainty of regulatory attitude towards Bitcoin; and 4) the possibility to disrupt the financial and payment markets if it finally replaces money transmission and card payment services.

1.1.2 The Rise of Central Bank-issued Digital Currency (CBDC) Initiative

As explained in Sub-section 1.1.1, one of the risks of cryptocurrencies is the unlawful usage, such as the vehicle for illegal transactions. This was one of several motivations for central authorities (in this case, central banks) to introduce their own version of digital currency called central bank-issued digital currency or CBDC. Although having ‘digital currency’ in its name, CBDC is not the same with other type of digital currencies, especially cryptocurrencies. The main difference between CBDC and cryptocurrencies is that cryptocurrencies are not the liability of anyone, while CBDC is the liability of the highly indebted central banks (Preiss, 2018).

Committee on Payments and Market Infrastructures (CPMI) of Bank for International Settlements (BIS) notes other motivations for central banks to introduce CBDC, including their interest in digital innovations in the financial sector, the emergence of new intermediaries and payment system providers, and the declining rate of cash usage in some countries (CPMI, 2018). The latter was one of the motivations for the Sveriges Riksbank (the central bank of Sweden) to start investigating the possibility to introduce e-krona, the digital version of Krona that will complement the cash (Sveriges Riksbank, 2017a). According to 2017 CPMI report on Statistics on payment, clearing and settlement systems in the CPMI countries, Sweden’s ratio of cash (notes and coins) in circulation outside banks to GDP shows a decreasing trend since 2012 to 2016, as shown in Figure 1. Their other motivations include the efforts to maintain stability of the payment systems by providing the digital version of risk-free central bank money and to broaden the opportunity for their citizens to “use digital payment solutions” (Sveriges Riksbank, 2017a, p. 4). Sveriges Riksbank (2017b) has specified timeline or action plan in 2018 for their e-krona project; by the end of 2018, they will decide whether they will continue (move to Phase 3 of the project, which is the development and implementation of e-krona) or conclude the project.

Sveriges Riksbank is not the only central bank that is interested in CBDC. There are several other central banks that show interest on and do research and experiments related to CBDC. For example, Bank of England conduct a research about macroeconomics impacts of CBDC (Barrdear & Kumhof, 2016). To quantitatively examine the possible consequences of introducing CBDC in the UK, they design a simulation using DSGE model that simulated the pre-crisis period in the US. The result shows that by issuing CBDC of 30% of GDP, GDP can be permanently raised by 3% (Barrdear & Kumhof, 2016).

⁴ However, as noted by Nian & Chuen (2015), “many Bitcoin exchanges are beginning to employ antimoney laundering features that include keeping records of their customers, which will reduce the attractiveness of Bitcoin to criminals” (p. 24-25). In addition, Bitcoin is hard to be counterfeited or double-spent due to its power-intensive transaction verification process (or mining process).

De Nederlandsche Bank or DNB (the central bank of the Netherlands) state that the study related to distributed ledger technology (DLT) and CBDC is one of their key initiatives in the future (De Nederlandsche Bank, 2018). Norges Bank (the central bank of Norway) publish a paper that reports the results of initial phase of their study on CBDC that include several possibilities of CBDC characteristics and designs and the impacts of CBDC to their payment systems and macroeconomy aspects, as well as the legal matters of CBDC (Norges Bank, 2018). Bank of Canada publish a paper that specifies motivations of a central bank to issue CBDC, possible designs of CBDC and how it will be managed, and the implications of CBDC related to the central bank seigniorage, monetary policy, the overall banking system and financial stability, and the contestability and efficiency in payments (Engert & Fung, 2017).

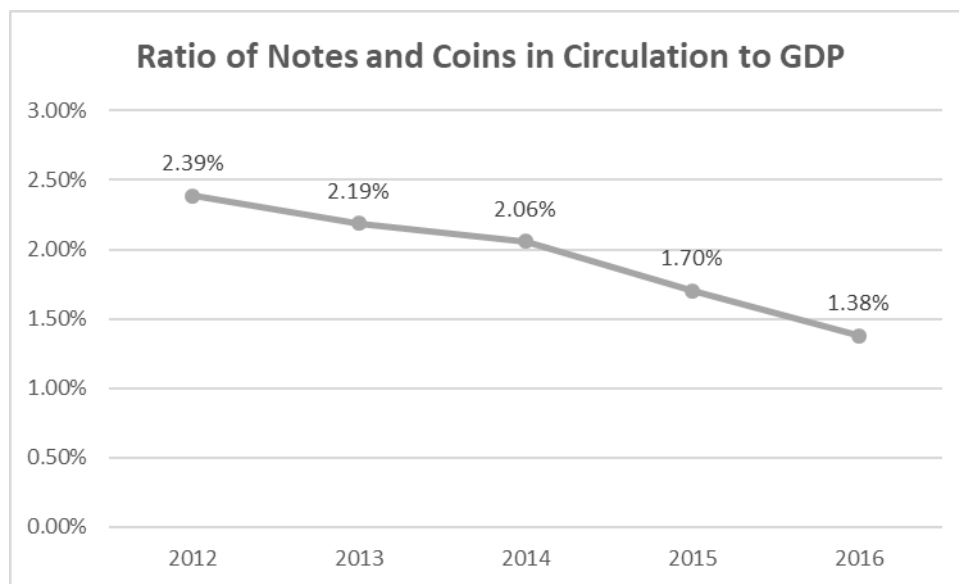


Figure 1 Sweden's Ratio of Cash (Notes and Coins) in Circulation to GDP

(Source: 2017 CPMI Report on Statistics on Payment, Clearing and Settlement Systems in the CPMI Countries)

1.1.3 Different Perspectives and Reactions on CBDC Initiative

Although the idea has been discussed for some years, CBDC is still a relatively new topic, and there is no common consensus of its definition and designs (Meaning, Dyson, Barker, & Clayton, 2018). Indeed, several central banks have published papers that discuss CBDC in details. However, each central bank has their own perspective and idea regarding the characteristics and implementations of CBDC, depending on many factors, such as their purposes of issuing CBDC and the economic conditions of their own country or economic zone. Examples of the different perspectives on CBDC design options can be seen in several aspects as follows.

- *Related to the characteristics of CBDC.* Bank of Canada consider two possible designs of CBDC: 1) a benchmark CBDC that has characteristics like cash, e.g., non-exclusive or universal access (everyone with proper technology can access it), non-interest-bearing, and anonymous; and 2) I-CBDC that is interest-bearing and non-anonymous (Engert & Fung, 2017). On the other hand, Bank of England focus on an interest-bearing, account-based CBDC that is non-anonymous (Meaning et al., 2018).
- *Related to the underlying technology of CBDC.* Scorer (2017) discusses the possibility of implementing CBDC using a distributed ledger technology (DLT) or a centralized technology.

He argues that the use of DLT on CBDC needs to be evaluated due to some risks; the distributed nature of DLT means many parties are required to validate the transactional data, thus opening the possibility of unauthorized data access (Scorer, 2017). But he also specifies several benefits of DLT on CBDC, such as the high level of operational resilience and less cost for the central bank to cope with a large volume of transactions when many people start using CBDC as their means of payment. On the other hand, Danezis & Meiklejohn (2016) introduce a framework of a fully decentralized cryptocurrency that is managed centrally by a central bank called RSCoin. The underlying technology of RSCoin is a blockchain-based with “relatively minimal alterations to the design of successful cryptocurrencies such as Bitcoin” (Danezis & Meiklejohn, 2016, p. 12).

In addition to the discussions related to the design options of CBDC, there are other discussions that focus on a more fundamental question: should central bank introduce CBDC? Not only the central banks but also the general public (e.g., academics and NGOs) try to answer this question. And, in addition to the studies done by the central banks to answer the question, some perspectives challenge the idea of CBDC as follows.

- Engert & Fung (2017) explain possible motivations for Bank of Canada to issue CBDC. However, based on the economic conditions in Canada, some of those motivations “are not compelling” (Engert & Fung, 2017, p. 22) and the reasons of other central banks in introducing CBDC, such as to preserve seigniorage and to promote financial inclusion, are not applicable to Canada (Engert & Fung, 2017). At the end of their report, Engert & Fung (2017) ask a fundamental question: “is a ‘cashless society’ a sound outcome?” (p. 24).
- Bank of Korea (BOK) in January 2018 established a task force to conduct research on CBDC and its impacts on “the payment and settlement systems and the entire financial system” (The Bank of Korea, 2018, vi), but in June 2018, they stated that CBDC has high social cost and may cause moral hazard, thus they finally opposed the idea of CBDC (Yoo-chul, 2018).
- Mr. Alex J. Pollock, a Distinguished Senior Fellow at R Street Institute, stated that CBDC is one of the worst financial ideas of the times (Alois, 2018; Partz, 2018) during a congressional hearing about cryptocurrencies held by the US Congressional Subcommittee on Monetary Policy and Trade in July 2018. According to Pollock (2018), CBDC will increase the monopoly power of central banks in the economy, and it should be avoided. In his testimony, he explained that by issuing its own digital currency to the general public, the Federal Reserve (The Fed) would be competing directly with all private banks by providing a service similar with (commercial) bank deposits. This would expand The Fed’s balance sheet to USD 10 trillion, thus opening the opportunities for The Fed to make loans and investments with that vast amount of deposits (Pollock, 2018). However, the credit allocation process “would unavoidably be highly politicized” (Pollock, 2018, p. 4). Therefore, he concluded that issuing CBDC is a terrible idea.
- Carsten (2018) explains that a retail CBDC or universal CBDC (U-CBDC), which allows non-banks entities to have accounts at the central banks and “is not anonymous, is supplied elastically, and is interest-bearing”, could have several undesirable consequences, such as: 1) causing the movement of substantial fraction of deposits from commercial banks to the central bank “with the remainder prone to exit in a period of financial stress”; 2) increasing cross-border fund movements from less stable economies to the stable ones if the stable ones were to

issue U-CBDC; and 3) changing the central bank into a commercial lender⁵, whose funds allocation may be politically interfered⁶. Therefore, Carsten (2018) concludes that there is “very little upside for central banks to issue retail digital currency”; instead there is “an enormous risk to the commercial banking system and political challenges for central banks.”

The increasing interest in CBDC and the dynamics of CBDC discussions motivated this research to provide another way in evaluating CBDC design options in addition to the works done by those central banks. The evaluation involved not only the perspective of major central banks (Bank of England and De Nederlandsche Bank) but also the perspective of a large commercial bank in a Eurozone country, regulatory bodies (a Ministry of Finance and a Financial Market Authority in a Eurozone country), and relevant NGOs (European members of International Movement for Monetary Reform or IMMR). By involving multiple perspectives, this research is expected to be able to add valuable insights into the ongoing CBDC discussions that might inspire other central banks and policymakers as well as provide an understanding of CBDC to broader audiences.

1.2 Problem Definition

Existing discussions and literature of CBDC, especially those that are published by central banks, are more focused on the discussions of the impacts of CBDC on economic and financial aspects, especially on the monetary policy, payment system, and financial stability (Meaning et al., 2018; Engert & Fung, 2017; Sveriges Riksbank, 2017a; CPMI, 2018), as well as the impacts on the central banks’ balance sheet (Kumhof & Noone, 2018; Sveriges Riksbank, 2017a).

However, little or no attention has been given to the possible transaction costs of the CBDC design options that might be borne by the impacted economic agents. Why are transaction costs important when evaluating CBDC design options? Before explaining the importance of transaction costs in this context, it is essential to define what ‘transactions’ and ‘transaction costs’ are in relation to CBDC.

To begin with, there is no single definition for transaction costs. McCann & Easter (2004) cite several definitions of transaction costs, such as the “costs of running the economic system” and “the expenses of organizing and participating in a market or implementing a government policy” (p. 2). Cordella (2006) defines transaction costs as the “the consequence of the asymmetrical and incomplete distribution of information among the economic agents involved in the transaction” (p. 196). Coase (1960) and Nolan & Trew (2011) define transaction cost as the cost to carry out market transactions that involves the cost of discovering information (collecting information), informing others to deal on certain terms (communicating), conducting negotiations for a bargain (bargaining), drawing up the contract, and enforcing the contract. A transaction itself can be defined as “the economic exchange between at least two individuals” (Cordella, 2006, p. 196).

The understanding of transaction costs was further developed by Oliver Williamson through his work, transaction cost economics (TCE). In its original context, TCE explains the reasons of the existence of firms, i.e., to maximize profits (or to minimize transaction costs). TCE rejects the neoclassical assumption that the market is perfect and efficient. This is due to the existence of transaction costs that

⁵ This is because of the expansion of the central bank’s assets due to the expansion of its liabilities after issuing CBDC, while the commercial banking is shrinking, reducing the sources of private credit.

⁶ This argument is the same with the argument stated in Pollock (2018).

coupled with two basic behavioral assumptions of an ‘economizing’ agent: bounded rationality and opportunism⁷. Regarding this context, Pessali (2006) explains that TCE “studies the uncertain world of incomplete contracts, inhabited by ‘contractual men’ – potentially opportunist people with bounded rationality” (p. 45). In TCE, transaction is the basic unit of analysis (Williamson, 1981a, 1981b) and there are three critical dimensions or attributes used by TCE to characterize transactions: 1) uncertainty; 2) the frequency of the transactions; and 3) the degree to which durable transaction-specific investments are incurred, or known as asset specificity (Williamson, 1979, 1981a, 1981b).

In the context of CBDC, a transaction can be seen as a process of exchanging information, goods, and services related to CBDC between two or more impacted economic agents. Thus, based on the previously mentioned definitions, the transaction costs of CBDC are the costs, efforts, or investments made by the impacted economic agents that are associated with any transactions related to CBDC. For example:

- For the central banks, transaction costs could be the costs of discovering the consequences of CBDC issuance to their operational aspects and the whole economic and financial system, conducting negotiations with all related parties (e.g., the commercial banks, the government, and the general public), drawing up the required protocols and regulations, and monitoring the implementation and post-implementation processes.
- For the commercial banks, transaction costs could be the costs of discovering the impacts of CBDC to their operational aspects and conducting their businesses under CBDC economy.
- For the government, transaction costs could be the costs of discovering the impacts of CBDC to the nation-wide economic, social, and political aspects and monitoring the economy after the introduction of CBDC.

Then, let us answer the previously asked question: why are transaction costs important when evaluating CBDC design options? CBDC, regardless of its design and purposes, might eventually have impacts in the broader economy. Transaction cost analysis helps the authorities (in this case, the monetary authorities or the central banks; and the government), to identify and evaluate the potential costs, efforts, or investments that need to be made by the impacted economic agents in relation to CBDC. In the end, it is expected that the transaction cost analysis can help to improve preliminary evaluations and screening across CBDC design options; enhance the effective design and implementation of CBDC to achieve the set objectives; and evaluate the implemented CBDC design in order to improve its effectiveness⁸.

To the researcher’s knowledge, current literature does not cover this topic (i.e., the evaluation of CBDC design options based on their transaction costs) in detail. Therefore, this literature gap will be addressed in this research by utilizing the TCE framework as the tool to characterize the transaction costs of several CBDC design options. By examining the factors related to the three transactional dimensions of TCE for each impacted economic agent, it is expected that the transaction costs of each CBDC design option can be characterized.

⁷ Bounded rationality refers to the limitations of the “capacities of individuals to receive, store, retrieve, and process information without error”, while opportunism refers to the “effort to realize individual gains through a lack of candor or honesty in transactions” (Williamson, 1973, p. 317). These two behavioral assumptions are explained in detail in Section 2.2.

⁸ Adapted from the work of McCann et al. (2005).

In addition to the above literature gap, current literature is dominated by the analyses from the perspective of central banks. This might cause biases during the decision-making process to determine the most proper CBDC design option because the opinions or perspectives of other related entities are excluded. Therefore, in efforts to balance out the discussion and to provide unbiased analyses, this research involves experts from different groups: central banks, commercial bank, regulatory bodies, and NGOs.

1.3 Research Scopes

The scopes of this research are as follows.

- This research captures existing design options of CBDC according to selected central banks, commercial bank, regulatory bodies, and NGOs. They may have published the detailed explanations of the designs. This research does not aim to introduce new or modify existing CBDC designs.
- This research characterizes the transaction costs of the CBDC design options using qualitative approach by utilizing existing TCE framework. This research does not introduce new framework or modify the core concept of TCE framework. Instead, this research applies the TCE framework into the contexts of CBDC.

1.4 Research Objectives

Based on the problems specified in Section 1.2 and the defined scopes in Section 1.3, this research is aimed to fulfill two objectives. First, since there are many perspectives on how CBDC can be issued, this research intends to provide a summary of possible CBDC design options and their respective characteristics according to central banks, commercial banks, regulatory bodies, and NGOs. By providing this summary, it is expected that this research could assist other central banks or related authorities that plan to explore CBDC in getting references on existing ideas of CBDC. In addition, since this research presents different perspectives, insights, and ideas, it is expected that there are no biases that could lead to a one-sided view of CBDC.

Second, this research intends to explore the transaction costs of each CBDC design option by applying transaction cost economics (TCE) framework. The transaction costs will be determined for each economic agent that will potentially be impacted by the CBDC issuance, depending on the CBDC design options. In addition, as there are no previous works that incorporate TCE framework into CBDC design analysis, this research serves as a preliminary literature that applies TCE framework as the lens in evaluating CBDC design options.

1.5 Research Questions

Based on the research problems and objectives that have been explained, this research answers following main research question.

Main-RQ: How can transaction cost economics (TCE) framework be applied to evaluate CBDC design options?

In order to answer this main research question, this research uses a systematic approach that consists of four steps that are organized into a sequential model as shown in Figure 2. Each step will answer a sub-research question and the output of one step will be the input of the next step. Eventually, the answers

of those three steps will form the answer to the main research question. The steps are explained and detailed in the following paragraphs.

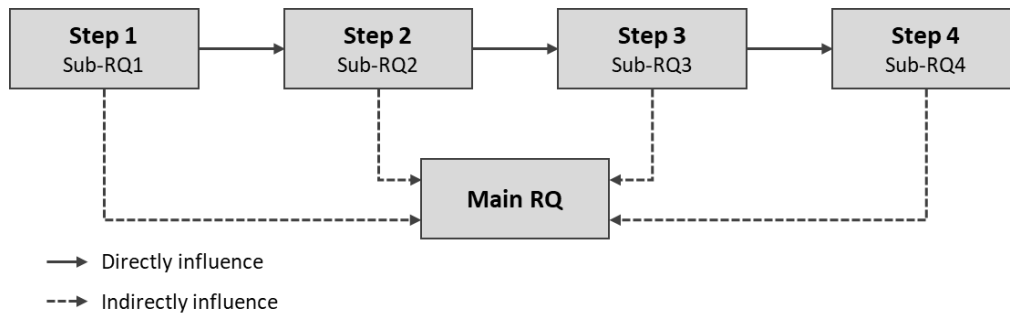


Figure 2 Sequential Steps to Answer the Main Research Question

The first step is to explore and determine the possible CBDC design options and their characteristics. This step is the most important part of this research since the output of this step will become the unit of analysis in the next steps. This step answers following sub-research question.

Sub-RQ1: What are the possible CBDC design options and their characteristics?

The second step is to determine the impacted economic agents in each CBDC design option. Depending on the CBDC design options, the impacted economic agents could be the central bank, commercial banks, other (non-bank) financial institutions, government, households, and other non-financial institutions. This step answers following sub-research question.

Sub-RQ2: Which are the impacted economic agents in each possible CBDC design option?

The third step is to determine the factors according to the transaction cost economics (TCE) framework that may impact each economic agent in each CBDC design option. The TCE transactional dimensions, which are uncertainty, asset specificity, and transaction frequency, may be too broad or abstract. Thus, it is important to operationalize them into factors that are specific to the context of CBDC. By determining the factors affecting the economic agents, the answer to the next step can be formulated. This step thus answers following sub-research question.

Sub-RQ3: What are the factors associated with the transactional dimensions of TCE that impact each economic agent in each CBDC design option?

Finally, the last step is to determine the transaction costs based on the factors identified in the third step. The characterized transaction costs will be used as the main evaluation components of the CBDC design options. This step thus answers following sub-question.

Sub-RQ4: What are the transaction costs for each economic agent in each CBDC design option?

1.6 Research Approach

To fulfill the research objectives and answer the research questions, this research is divided into two main phases, which are: 1) semi-structured interview sessions and 2) data analysis and interpretation. Before the first phase is performed, a preliminary study, which is a literature review, is done. The literature review is important to establish the initial context and understanding of the topics covered in

this research so that the main phases can be done. In this preliminary study, the basic understanding of the concept of money is provided, including the functions of money, the theories of the emergence of money, the classification of money, and the digital forms of money (digital currency, cryptocurrency, and CBDC). In addition, this preliminary study provides more profound understanding of two main aspects of transaction cost economics (TCE) framework that are briefly mentioned in Section 1.2, which are the basic behavioral assumptions of ‘economizing’ economic agents and the transactional dimensions of TCE.

The preliminary study is then followed by the first phase of the research, which is a set of semi-structured interview sessions⁹. The semi-structured interview enables the researcher to gain knowledge, views, and insights from the interviewees related to the CBDC design options and the potential transaction costs incurred by impacted economic agents in each design option. The semi-structured interview is designed to answer the first three sub-research questions. The results of the interview sessions are then transcribed and coded so that the researcher is able to extract and connect the key concepts and ideas of the interviewees.

The second phase is the analysis and interpretation of the results of the semi-structured interview sessions. In this phase, the coded results of the interviews are analyzed and interpreted so that the meaning of the interview sessions can be constructed. This phase is performed to answer the last sub-research question and finally to answer the main research question. Table 1 summarizes all the phases, activities, and outputs of this research, as well as the covered research questions in each phase.

Table 1 Phases of the Research

Phase or Process	Activities	Output	Related RQ
Preliminary Study: Literature Review	Literature study on money: <ul style="list-style-type: none"> • functions of money • theories of the emergence of money • classification of money 	<ul style="list-style-type: none"> • Preliminary understanding of CBDC concept and available design options • Conceptual model 	-
	Literature study on digital currency, cryptocurrency, and CBDC		
	Literature study on TCE framework		
Phase I: Semi-structured Interview Preparation, Execution, and Coding	Interview protocol design	Interview protocol	-
	Interviewees selection	List of interviewees ¹⁰	-
	Interview invitation	-	-
	Interview sessions: pilot and actual	Interview recordings ¹¹ and notes	<ul style="list-style-type: none"> • Sub-RQ1 • Sub-RQ2 • Sub-RQ3
	Interview transcribing	Interview transcriptions	
	Interview coding	Coded interview data	

⁹ Further explanation of how the semi-structured interview is prepared and executed can be seen in Section 3.1.

¹⁰ Some of interviewees are the author of several papers that used in this research.

¹¹ All the recordings were approved by the interviewees and then deleted after transcribed to ensure the privacy of the interviewees.

Phase or Process	Activities	Output	Related RQ
Phase II: Data Analysis and Interpretation	Analysis and interpretation of the coded interview data	<ul style="list-style-type: none"> • Interpretation of interview results • Discussion of the interview results 	<ul style="list-style-type: none"> • Sub-RQ4 • Main-RQ

1.7 Structure of the Report

The remaining of the report is organized as follows. **Chapter 2** provides the explanations of main concepts and theory used in this research based on existing literature. Those concepts are: 1) the functions of money, theories of the emergence of money, and classifications of money; 2) the new digital forms of money, i.e., digital currency, cryptocurrency, and CBDC; and 3) transaction cost economics (TCE) framework that will be used as the evaluation basis of this research. This chapter also presents the conceptual model used in this research. **Chapter 3** elaborates the methodology used in this research. **Chapter 4** presents the results of the semi-structured interviews and the analysis of the results. **Chapter 5** provides the conclusions that answer the research questions, the scientific contribution of this research, and the recommendations for future research.

2 Chapter 2 – Literature Review

This chapter explains the main concepts used in this thesis based on existing literature. There are two main concepts that underlie this thesis: 1) money; and 2) transaction cost economics (TCE) theory.

2.1 Money

2.1.1 Functions of Money

As one of mankind's essential social technologies (Ingham, 2004), money has been studied, defined, and explained by many scholars, including Adam Smith, Jevons (1896), Holdsworth (1914), Milnes (1919), Scott (1920), Keynes (1930), Ingham (2004), and Lawson (2016). This sub-section provides the review of several theories found in existing literature related to the functions of money in the society. The review will be based on four standard or familiar functions of money that mainly discussed on many economic textbooks, as noted by Ingham (2004) and Lawson (2016), which are: 1) medium of exchange; 2) store of value; 3) means of unilateral payment or settlement; and 4) measure of value (several authors mention this function as the unit of account).

Many discussions in the literature revolve around money's functions as a medium of exchange and a measure of value (or unit of account in several literature). In discussing these functions, classical and neoclassical economists tend to emphasize the importance of money as the remedy of the difficulties in barter. Adam Smith, in his work titled *An Inquiry into the Nature and Causes of the Wealth of Nations* that was first published in 1776, explains that due to the division of labour, people start doing barter by exchanging their surplus with their wants. Money, as a medium of exchange, takes place to overcome the double coincidence of wants (this will be explained in detail in sub-section 2.1.2.1). He also argues that money is more frequently traded with other commodities, therefore money is used more in estimating value¹². Thus, he emphasizes the two functions of money: "that wealth consists in money, or and silver, is a popular notion which naturally arises from the double function of money, as the instrument of commerce and as the measure of value" (p. 398). Similarly, Mill (1865) emphasizes that "the inconveniences of barter are so great, that without some more commodious means of effecting exchanges, the division of employments could hardly have been carried to any considerable extend" (p. 4). In his view, money is merely precious commodities, such as gold, silver, and jewels, that serve as the medium of exchange. Another scholar, Jevons (1896), starts his explanation about the functions of money by describing the difficulties in barter, such as the double coincidence of wants and the difficulty to divide the exchanged goods to meet the agreed value in the transaction. Thus, he explains, money serves two very important functions: as a medium of exchange and a common measure of value¹³. Also, Milnes (1919) defines money as "a third commodity, chosen by common consent to be a medium of exchange and a measure of value, between any and every other two commodities" (p. 54)¹⁴. Similar with the other scholars, he explains that money is the remedy for the difficulties in barter: "the difficulty of the non-mutuality of want and its supply, and the difficulty of estimating values" (p. 53).

¹² Smith (1776) argues that "labour is the real measure of the exchangeable value of all commodities" (p. 30). However, as "labour is difficult to measure" (Smith, 1776, p. 31), he explains that money can be used to estimate value, although "the nominal prices themselves are adjusted on the basis of the labor expended in both the production of money and other commodities" (Henry, 2000, p. 4).

¹³ Additionally, he mentions that money serves as a standard of value and a store of value.

¹⁴ Milnes (1919) then summarizes four money functions as "a Medium, a Measure, a Standard, a Store" (p. 55).

Above pieces of literature mention several commodities that were used as money (mainly as a medium of exchange and a measure of value), such as precious metals (gold and silver), cattle, sugar, and iron. However, not all commodities can be used as money. Hill (2018) explains that in order to perform the function as a medium of exchange, a commodity should have wide acceptance (accepted by all transacting parties), not extremely volatile (has stable valuation), establish confidence (because backed by the government), have right denomination, be portable, be durable, and be secure. Also, in order to perform the function as a measure of value, a commodity should be applicable widely (can be used to measure or price a wide range of goods and services) and reduce costs that are required to discover and compare relative value and prices between goods and services (Hill, 2018).

Although the classical- and neoclassical-proponent literature focuses on money function as a medium of exchange, there are several views which argue that the medium of exchange is not the main function of money. Instead, it may be considered as the ‘secondary’ function (together with other functions) in which the primary function is as a measure of value. As explained by Ingham (2004), “money is uniquely specified as a *measure of abstract value* (money of account); and as a *means of storing and transporting* this abstract value (for means of final payment or settlement of debt)” (p. 70). This view emphasizes the abstract characteristics of money; that money is intangible. Ingham (2004) argues that this abstraction of money represents a provisional ‘promise’ to pay that is used to cancel “any debt incurred by the issuer” (p. 12). This abstraction also represents the purchasing power that is possessed by money, which “exists independently of the goods it can buy” (Ingham, 2004, p. 70). This argumentation is based on prior literature such as Keynes (1930), which opened by an emphasize on the primary function of money as unit of account: “Money-of-account, namely that in which Debts and Prices and General Purchasing Power are *expressed*, is the primary concept of a Theory of Money” (p. 3). Other pieces of literature, such as Lawson (2016), emphasize that the primary function of money is as a general means of payment. In this context, money (or anything that is positioned as money) is used to discharge obligations or debts.

In addition to the previously discussed functions, Jevons (1896) and Milnes (1919) mention that money acts also as a standard of value and a store of value. As a standard of value, money enables all economic agents to set or agree on standard or uniform prices for transacted goods and services. In this context, money serves as universal language for all participating economic agents in determining or measuring values or prices of the goods and services. Some pieces of literature, such as Holdsworth (1914) and Scott (1920), do not make clear distinction between standard of value and measure of value functionalities. In their views, a commodity that serves as standard or measure of value has one purpose, i.e., to “measure and express the value of other commodities” (Scott, 1920, p. 2). As a store of value, it is expected that money is able to store and retain its value over a reasonable period of time; that is, its value does not decrease or vanish quickly, so it can be used for deferred spending (Hill, 2018). Related to this function, Ingham (2004) argues that “money is able to store abstract value, as pure purchasing power, for longer periods than is necessary for any particular exchanges” (p. 3). In this context, money should be able to provide sufficient liquidity that can be used freely in the future for “multiple purposes without having to first be transformed” (Hill, 2018, p. 43) and provide confidence that its value will not degrade rapidly (as what happens in hyperinflation).

2.1.2 Different Theories of the Emergence of Money

Discussions on the functions of money cannot be separated from the discussions on the emergence of money. For many years, scholars have been trying to propose theories related to the emergence of money, along with its functions. Following sub-sections describe different theories that try to explain

how money came into and developed in human's civilization. Those theories can be divided into two groups based on the main function of money they emphasize. Barter theory emphasizes money's function as a medium of exchange, while both the Credit Theory of Money and the State Theory of Money emphasize money's function as a unit of account and a means of payment. Goodhart (1998) classifies the theories into two groups: the Metallists, which argue that "money evolved as a private sector, market-oriented, response to overcome the transactions costs inherent in barter" (Goodhart, 1998, p. 408); and the Cartalists, which argue that "the State has generally played a central role in the evolution and use of money" (Goodhart, 1998, p. 408).

2.1.2.1 Barter

Barter theory is mainly used by classical and neoclassical economists to explain the emergence of money. According to this theory, before using money, human used a mechanism called barter in trading goods and services to fulfill their needs or wants, and money emerged to overcome the impracticalities in barter. In this theory, money is considered neutral; it does not have any effects on the growth of the economy. Money is a 'neutral veil', a highly liquid commodity (Ingham, 2004) that only emerges in the society to remedy the double coincidence of wants of barter. Money is merely a type of common commodity that acts as the medium of exchange to facilitate easier transactions. Because the proponents of this theory argue primarily that the coins made of precious metals (gold, silver, and copper) are the money, they are called the Metallists.

As has been explained in Sub-section 2.1.1, Smith (1776) argues that when the division of labour is established, people start living by exchanging and society grows to be a commercial society. In his view, barter is defined as a mechanism of "... exchanging that surplus part of the produce of his own labour, which is over and above his own consumption, for such parts of the produce of other men's labour as he has occasion for." (p. 22). In short, this mechanism of exchange allows two parties to meet and trade goods based on what they want (deficit of) and what they have (surplus of). For example, one party produces rice and wants sugar and the other party produces sugar and wants rice. By doing barter, they trade their surplus of rice and sugar, respectively, so that they can have what they want.

However, this system is not practical (Skingsley, 2016) and has several disadvantages and inconveniences. Civilization then shifted to the use of money as money can remedy the difficulties and inconveniences in barter, as noted by Smith (1776) as follows.

"In order to avoid the inconveniency of such situations, every prudent man in every period of society, after the first establishment of the division of labor, must naturally have endeavored to manage his affairs in such a manner, as to have at all times by him, besides the peculiar produce of his own industry, a certain quantity of some one commodity or other, such as he imagined that few people would be likely to refuse in exchange for the produce of their industry." (p. 22–23).

In his book, *Money and the Mechanism of Exchange*, Jevons (1896) points out three difficulties in barter that led to the 'invention' of money. First, barter requires two parties to possess disposable goods that mutually suit each other's wants. Jevons calls this condition as 'double coincidence of wants' that has low probability to happen. The time and efforts used to make double coincidence to happen could be used for more productive activities. The solution for this difficulty is by using common commodities "which all are willing to receive for a time, so that what is obtained by sale in one case, may be used in purchase in another" (Jevons, 1896, p. 4). This kind of commodities acts as a medium of exchange,

which is an intermediary instrument or entity that has standardized value and accepted by both transacting parties.

Second, in barter, it is difficult to measure the acceptable amount or quantity (or value) of exchanged goods. In the example transaction in the previous paragraph, both parties will probably ask each other: how much rice for how much sugar and how much sugar for how much rice? They may agree in a specific rate in that one transaction, but if the transacting parties are involved in other transactions with different exchanged goods or different counterparties, the previously agreed rate or quantity may not be applicable. The solution for this difficulty is by using a kind of commodity that acts as a common denominator or common measure of value, “in terms of which we estimate the values of all other goods, so that their values become capable of the most easy comparison” (Jevons, 1896, p. 5–6). For example, it is easier to determine how much rice can be exchanged for one kilogram of silver and how much sugar can be obtained for the same amount of silver. In this case, silver acts as a common denominator commodity that makes transacting parties easy to measure the value of their goods.

Third, in barter, it is difficult or inconvenient to divide the exchanged goods to meet the agreed value in the transaction. In the previous example, rice and sugar may be easy to be portioned out and their value will depend on the portions. But, other goods may not be easy to be divided without decreasing its value. For example, a carpenter has just finished an exotic table to be exchanged and he wants a piece of shirt from a tailor and a loaf of bread from a baker. The value of his table is much higher than the shirt and the bread and it is impossible for him to break down his table because its value will be destroyed. Thus, he needs a commodity that acts as a medium of exchange and a common measure of value so that he can easily obtain what he wants.

2.1.2.2 Credit Theory of Money and State Theory of Money

To some extent, barter theory sounds logical in explaining how money emerged to eliminate the double coincidence of wants, thus it could facilitate commercial transactions in the society. According to barter theory, the history of the monetary system was started from barter, then the invention of money, and finally the development of credit systems. However, as argued by Graeber (2011), the process of the development of the monetary system was the other way around. In addition, the barter economy did not actually happen; it was “a purely imaginary exercise” (p. 23) of the most economic textbooks. There is no historical evidence of barter economy, as noted by Caroline Humphrey in Graeber (2011) as follows.

“No example of a barter economy, pure and simple, has ever been described, let alone the emergence from it of money; all available ethnography suggests that there never has been such a thing.” (p. 29).

Graeber (2011) supports his argument by explaining that several Mesopotamian tablets were found “recording credits and debits, rations issued by temples, money owed for rent of temple lands, the value of each precisely specified in grain and silver” (p. 21). He describes that the Temple bureaucrats in the ancient Sumerian society developed “a single, uniform system of accountancy, ..., to calculate debts (rents, fees, loans ...) in silver” (p. 39). At that time, silver was used as money, but it was not used as a medium of exchange as it did not circulate in a large amount; most of them stayed guarded in the Temple or Palace treasuries. Instead, it was used to calculate the prices and debts that were issued by the Temple or Palace. Most transactions carried out in the economy used credit mechanism.

In short, early society started to establish a commercial mechanism by constantly creating and canceling debts and credits (Innes, 1913), not by exchanging commodities. This theory of the emergence of money

is called the Credit Theory of Money, that was proposed primarily by Alfred Mitchell-Innes through his two papers, *What is Money* and *The Credit Theory of Money*, which were published in the *Banking Law Journal* (in 1913 and 1914, respectively). Innes (1913) describes that money appears as the debts (and credits) appear, and it will disappear when the debts are paid off, as noted by him, “money, then, is credit and nothing but credit. A's money is B's debt to him, and when B pays his debt, A's money disappears” (p. 402). In his view, commercial transactions involve the process of exchanging debts and credits. Innes (1914) then further defines his theory as follows.

“Shortly, The Credit Theory is this: that a sale and purchase is the exchange of a commodity for credit. From this main theory springs the sub-theory that the value of credit or money does not depend on the value of any metal or metals, but on the right which the creditor acquires to “payment,” that is to say, to satisfaction for the credit, and on the obligation of the debtor to “pay” his debt and conversely on the right of the debtor to release himself from his debt by the tender of an equivalent debt owed by the creditor, and the obligation of the creditor to accept this tender in satisfaction of his credit.” (p. 152).

In contrast to barter theory, this theory emphasizes the function of money as an abstract unit of account (or a measure of value); “money is not a commodity but an accounting tool” (Graeber, 2011, p. 46), that is used to measure debt. In this theory, money is an IOU that represents a promise to pay that can be circulated in the society. The IOU contains purchasing power that can be transferred or circulated; therefore, the IOU “began to circulate as means of payment” (Ingham, 2004, p. 38).

The process of the emergence of money from credit can be described as follows (as described by Graeber (2011)).

- A gives a coat to B, and B promises something to A with an equivalent value to pay the coat. In this context, B provides an IOU to A.
- After obtaining the IOU, A could pass the IOU to other parties, C. In this point, B owes the C an equivalent value that B previously promises to A.
- C could use the IOU to buy other things that he/she needs from D.

In this process, as long as A can assure C that B will pay the promised value (also, C can assure D, and so on), the process will continue for years, provided the society continues to have faith in B (Graeber, 2011). This is where the money is born. Graeber (2011) notes, “in this sense, the value of a unit of currency is not the measure of the value of an object, but the measure of one's trust in other human beings” (p. 47).

Similar with the Credit Theory of Money, the State Theory of Money emphasizes the function of money as a unit of account. In addition to the unit of account function, it emphasizes the function of money as a general means of payment. State Theory of Money was prominently introduced by Georg Friedrich Knapp in his book, *The State Theory of Money*, that was first published in 1905 to oppose the orthodox view of money in which money is used primarily as a medium of exchange. His main argument is reflected in the two first sentences in this book: “Money is a creature of law. A theory of money must therefore deal with legal history” (Knapp, 1924, p. 1). In his view, the emergence of money cannot be separated from the sovereignty or legal aspect of the state. He emphasizes that money is created by the state as a uniform nominal unit of account that is used to measure and settle debts, especially tax debts. What the state determines as acceptable to pay tax at public pay offices will become legal currency

(Graeber, 2011); as noted by Ingham (2004): “by declaring what it will accept for the discharge of tax debt, assessed in the unit of account at the public pay offices, the state creates money” (p. 47).

2.1.3 Classifications of Money

Money can be distinguished into various types based on its attributes or characteristics. This sub-section provides a review of several pieces of literature that classify money into different categories using different terminologies.

Kahn & Roberds (2009) classifies money based on the payment systems. They classify payment systems into ‘store-of-value systems’ and ‘account-based systems’. In store-of-value payment systems, money is a payment object (e.g., commodity money, coins, or bank notes) that is perfectly liquid and owned by the payer. In this context, when the payment occurs, the payment object (the money) is transferred from the payer to the payee; its ownership is changed from the payer to the payee. In the account-based system, money is a “claim on a payment object” (He et al., 2017) that recorded in the payer’s account and when the payment occurs, the claim is transferred to the payee’s account. Charge accounts, checks, and credit cards are examples of account-based payment. In their work, Kahn & Roberds (2009) defines the “Platonic ideal” for the store-of-value system as “spot trades using perfectly liquid assets” (p. 6) and for the account-based system as “pure, costless credit” (p. 6). We can define assets as current ownership and credit as a future claim.

In another piece of literature, Graeber (2009) distinguishes money into ‘commodity’ money, which has a role as a medium of exchange for the transactions of other commodities, and ‘debt’ money, which is created because of debt. As opposed to ‘commodity’ money, ‘debt’ money does not emerge from an exchange, “it is rather a means for accounting for and settling debts, the most important of which are tax debts” (Ingham, 2004, p. 47). Graeber (2009), citing Knapp’s work in *The State Theory of Money*, argues that in this context:

“money arose not as a medium of exchange but as a unit of account (and secondarily, means of payment), specifically, as a way of assessing and levying tax payments. Money here is a way of managing debt, starting with the debt that subjects or citizens were assumed to have to their sovereign. In order to do so, the state must establish the nominal units of account, and fix the conversion rates between commodities.” (p. 110).

In Kahn’s and Roberds’ terminology, ‘commodity’ money can be seen as a payment object (in store-of-value system) and ‘debt’ money is related to account-based system (as debt can be seen as a form of credit or deferred payment).

Michael Kumhof, in his presentation in 2015 Bank of England (BoE)/Centre for Central Banking Studies (CCBS) Chief Economists’ Workshop titled *Digital Currencies – What History Teaches Us*, explains that as a medium of exchange, money can be distinguished based on two key characteristics, i.e., what technology constitutes money and how trust is generated in money. Based on its technology, Kumhof (2015) argued that money can be distinguished into token-based money and credit-based money. Token money is money that represents greater value than its intrinsic value (i.e., the value of the materials used to create or mint the money). Related to this definition, Jevons (1896) explains that “token coins, on the contrary, are defined in value by the fact that they can, by force of law or custom,

be exchanged in a certain fixed ratio for standard coins¹⁵” (p. 74). Modern coins and banknotes are examples of token money. Token money can be defined not only as a medium of exchange, but also as a store of value that represents the money itself, or the ownership of money. On the other hand, credit money is a “sort of money which constitutes a claim against any physical or legal person. But these claims must not be both payable on demand and absolutely secure...” (von Mises, 1953, p. 61). Also, von Mises adds, “... In some way or other the maturity of these claims must be postponed to some future time” (p. 61). Credit money does not represent the ownership of money; money does not store value, but it measures value. Graeber (2011) argues that in this view, money is used to measure debt (money is a measure of value). Thus, credit-based money ultimately represents debt (Kumhof, 2015). Bonds and money market account are the examples of credit money.

Based on how trust is generated, Kumhof (2015) argued that money is distinguished into sovereign-power money and private-arrangements money. This classification is related to the control of the issuance of money, whether it is government/state issuance (sovereign-power money) or private issuance (private-arrangements money). According to Benes & Kumhof (2012), privately-issued money is based on debt and this kind of money has historically led to major financial crises “due to usury associated with private debts” (p. 13), while government-issued money is debt-free. In other literature, such as McMillan (2014)¹⁶, government-issued money is called outside money, because it is created by the government out of the commercial (private) banking system, while privately-issued money is called inside money as it is created within the commercial banking system. Cash, central bank reserves, CBDD, and public digital cash system are the examples of outside money, and bank deposits are examples of inside money.

2.1.4 Digital Forms of Money

This sub-section provides explanations of digital currencies and CBDC.

2.1.4.1 Digital Currencies and Cryptocurrencies

In general, digital currencies can be defined as the digital or electronic form of currency. Committee on Payments and Market Infrastructures (CPMI) of Bank of International Settlements (BIS) in their paper titled Digital Currency explains that digital currencies are the subset of electronic money (or e-money). E-money is defined as “value stored electronically in a device such as a chip card or a hard drive in a personal computer” (Committee on Payments and Market Infrastructures, 2015, p. 4). E-money then can be distinguished into two groups: legally recognized e-money and digital currencies. ‘Legal’ means that it is regulated under a particular jurisdiction and “denominated in the same currency as central bank or commercial bank money, and can easily be exchanged at par value for them or redeemed in cash” (CPMI, 2015, p. 4). For example, the value stored in a prepaid public transportation smart card (e.g., OV-chipkaart in the Netherlands). On the other hand, digital currencies may not be regulated under a particular jurisdiction and may not be denominated in the prevailing currency; they may be denominated “in their own unit of value” (CPMI, 2015, p. 4). That means digital currencies can be used for cross-border payments or transactions, as long as the transacting parties accept them as means of payment.

¹⁵ As opposed to token money, standard money (or standard coin) is a form of money whose value “*depends solely upon the value of the material contained in it*” (Jevons, 1896, p. 74).

¹⁶ Jonathan McMillan is a pseudonym of two authors of *The End of Banking*. One of the author is a financial expert that worked in the financial centers of London and New York and the other is Jürg Müller that holds an M.Phil. in economics from University of Cambridge and Ph.D. in economics from ETH Zurich.

Also, because they have their own unit of value, they can be exchanged with the legal currency with a certain exchange rate. Then, based on its underlying technology and how it is managed, digital currency can be distinguished further into two types: centralized and decentralized. Centralized digital currency is issued and managed centrally by a company within a closed system (Nian & Chuen, 2015) and its usage is usually strictly controlled and monitored by the company. For example, PokéCoins in Pokémon Go game that can be used to purchase in-game items. In contrast to the centralized digital currency, the decentralized (or distributed) one is not issued by a specific company or entity and utilizes an underlying decentralized technology (distributed ledger technology or DLT) to facilitate transactions. Cryptocurrencies, such as Bitcoin and Ethereum, are examples of decentralized digital currency (Nian & Chuen, 2015). This classification of e-money and digital currency is described in Figure 3.

According to Nian & Chuen (2015) and CPMI (2015), cryptocurrencies have several key characteristics that distinguish them from other forms of e-money. First, from the perspective of their institutional arrangements, as has been stated in the previous paragraph, it is decentralized, which means it is not issued and controlled by a single authority. Other forms of e-money usually represent “liabilities on the issuers’ balance sheets” (CPMI, 2015, p. 5) and involve several service providers to operate, including “the network operators, the vendors of specialized hardware and software, the acquirers of e-money, and the clearer(s) of e-money transactions” (CPMI, 2015, p. 5). On the other hand, cryptocurrencies are not issued by a specific company or institution, thus they are not liabilities of any companies or institutions. Second, unlike fiat currency (legal currency that is backed by the government) that theoretically has a limitless supply (as the supply is controlled by the central bank), cryptocurrencies are assets with limited supply. Their supply is usually predetermined in their underlying algorithm and the creation of new units is controlled by a certain protocol (CPMI, 2015). For example, in its current configuration, Bitcoin’s supply is limited to 21 million coins (Antonopoulos, 2014). This limited supply is designed to maintain its scarcity (CPMI, 2015) which partly determines the value of Bitcoins¹⁷ (Greenberg, 2011). And to create a new block of Bitcoins (or mining), one needs to solve a predetermined mathematical problem that is a computationally intensive process (Nian & Chuen, 2015). Third, due to their decentralized nature, cryptocurrencies allow transactions and payments to be done anonymously¹⁸ and peer-to-peer (directly from the payer to the payee without third party’s involvement, e.g., financial institutions or central banks). The transactions are facilitated by the distributed ledger technology “to allow remote peer-to-peer exchanges of electronic value in the absence of trust between the parties and without the need for intermediaries” (CPMI, 2015, p. 5).

¹⁷ Other factor that determines Bitcoin’s value is the willingness of the society to accept it as a means of payment (Greenberg, 2011).

¹⁸ Some (e.g., Mas & Chuen (2015)) argue that transactions using private cryptocurrencies are not fully anonymous; although the involved parties do not need to exchange their identity information, their transactions are still traceable in the blockchain network, therefore the transactions are considered pseudoanonymous.

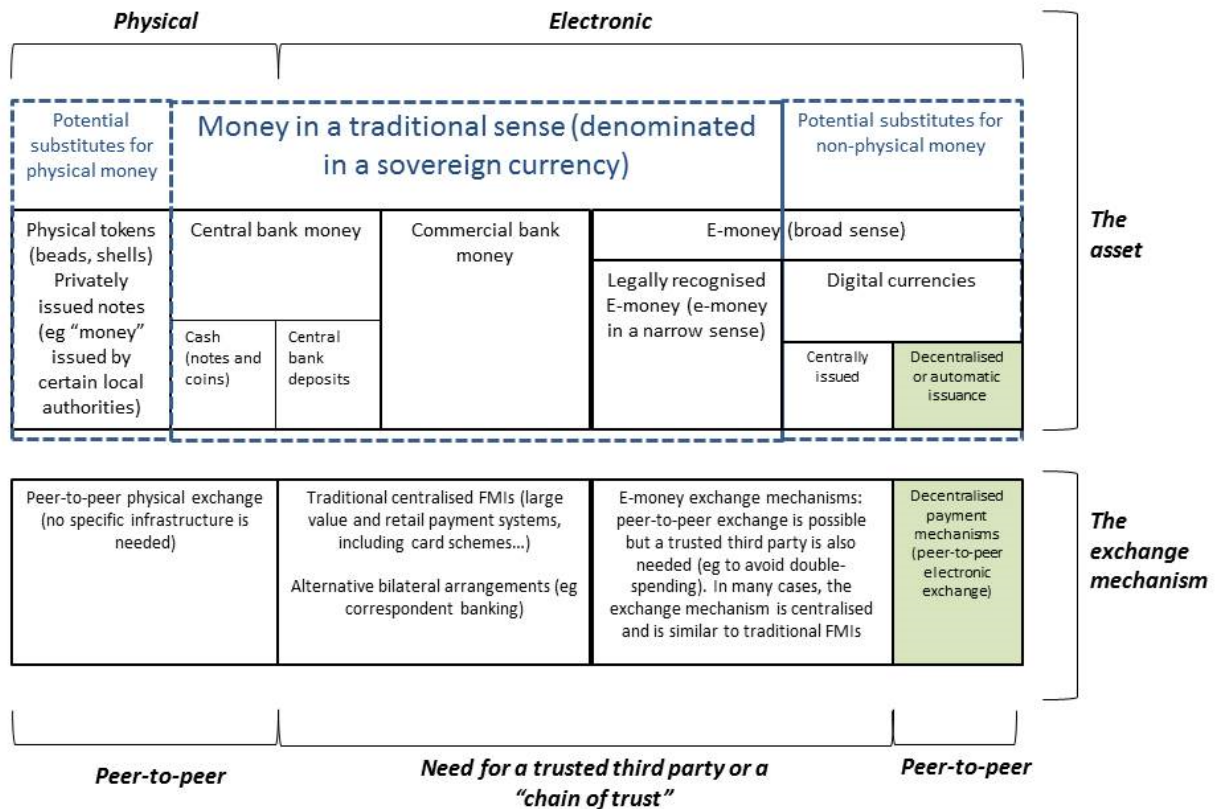


Figure 3 General Taxonomy of Money and Its Exchange Mechanism (CPMI, 2015)

Authorities (governments and central banks), do not fully see cryptocurrency as socially beneficial. First, the anonymous, peer-to-peer, and decentralized natures of private cryptocurrencies have raised governments' concerns on their use for money laundering, tax evasion, and payment for illegal transactions. Several illegal e-marketplaces (or online black markets), such as Silk Road¹⁹, relied on Bitcoin as the medium of payment. Second, a relatively high amount of energy for computing capacity is required to do transactions using cryptocurrency. Transactions settled using cryptocurrency need to be verified within the cryptocurrency's network. During the verification process, the verifiers "compete against each other in searching for a cryptographic proof of work – a verifiable demonstration that they have paid a cost in computation time – to accompany their candidate block of transactions" (Barrdear & Kumhof, 2016, p. 6). The verification process requires extensive computing power to solve certain computational problems and the verifiers will be compensated by a portion of the cryptocurrency. However, there is only one verifier that will be successful. Because the probability of one verifier to be successful is proportional to the computing capacity they deploy and the difficulty of computational problem is adjusted consistently, there is an incentive for the verifiers to "overinvest in their own computing capacity" and "since coordination is not possible, in equilibrium a socially inefficient excess of computing capacity will be deployed" (Barrdear & Kumhof, 2016, p. 7). Digiconomist, a website that presents the statistics of Bitcoin's energy consumption, states that current Bitcoin's estimated annual electricity consumption is around 73.12 TWh (as per August 2018). This electricity consumption is higher than the electricity consumption of several countries as presented in Figure 4.

¹⁹ Silk Road has been shut down by FBI in 2013 and its founder, Ross William Ulbricht, has been arrested and was sentenced to life in prison (Hsu, 2017).

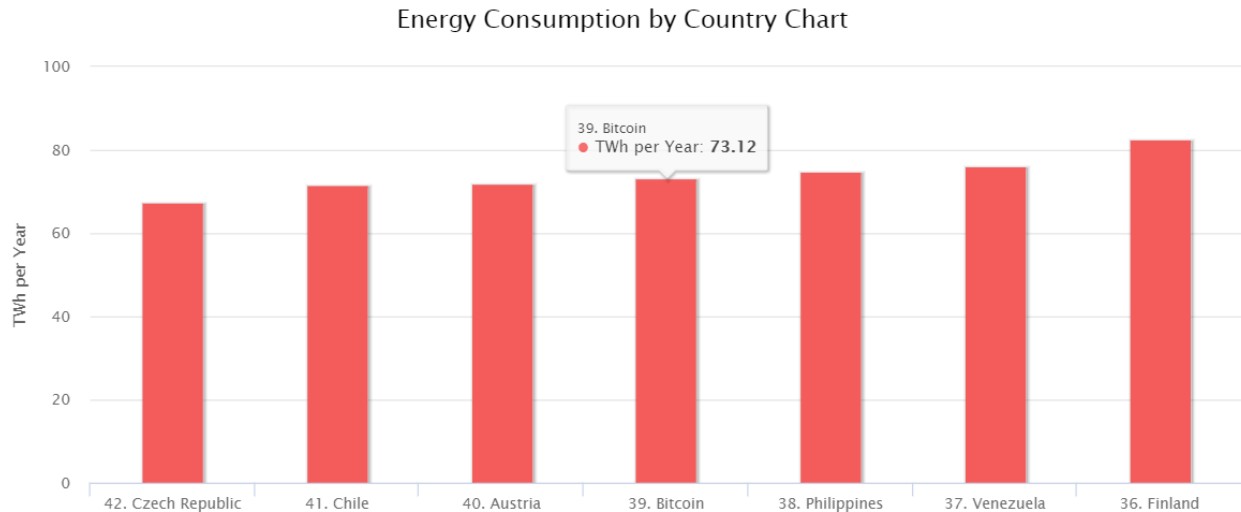


Figure 4 Bitcoin’s Energy Consumption Compared to Several Countries

(source: <https://digiconomist.net/bitcoin-energy-consumption>)

2.1.4.2 Central Bank Digital Currency (CBDC)

As explained in Chapter 1, there are many definitions of CBDC; each central bank has their own view of the definition and characteristics of CBDC. Meaning et al. (2018) from Bank of England offer a general definition for CBDC as follows.

“Central bank digital currency is *any electronic, fiat liability of a central bank that can be used to settle payments, or as a store of value*. As such, CBDC can be viewed as electronic narrow money and in some senses already exists in the form of central bank reserves.” (p. 2).

This general definition does not define any specific characteristics of CBDC, therefore Meaning et al. (2018) add that within this definition, “there exists a wide range of sub-characteristics and parameters that could be set or varied” (p. 4). This statement reflects the various characteristics and parameters that can be applied to CBDC, depending on the purposes of the CBDC. Meaning et al. (2018) specify several parameters that will differentiate the perspectives of CBDC among the central banks as follows.

- *Accessibility of CBDC.* CBDC can be designed to be universally accessible (can be accessed by anyone for any purpose) or restrictedly accessible (the access is limited to a certain group of economic agents for a specific set of purposes). Barrdear & Kumhof (2016), Bjerg (2017), Engert & Fung (2017), Sveriges Riksbank (2017a), and Norges Bank (2018) focus on CBDC with universal access. On the other hand, Bech & Garratt (2017) and Mersch (2017) consider central bank digital money that can only be accessed by commercial banks. Bech & Garratt (2017) refer to this type of central bank digital money as wholesale central bank cryptocurrency (CBCC), while Mersch (2017) uses another terminology: Digital Base Money (DBM).
- *Interest-bearing or non-interest-bearing.* CBDC can be designed to pay certain interest rates (could be positive or negative rates). This type of CBDC could be used by a central bank for several purposes, for example, as the primary instrument of monetary policy or to regulate the demand of CBDC itself. CBDC can also be designed to be interest-free, i.e., it does not pay any interest, just like cash. Sveriges Riksbank (2017a) designs e-krona initially as interest-free, but it “should have a built-in function to make it possible to accrue interest at a later point” (p. 6).

- *Trades at par or at certain exchange rates with other central bank liabilities.* This parameter is closely related to the previous parameter (interest-bearing vs. non-interest-bearing). Parity means that CBDC can be exchanged 1:1 with other central bank liabilities, such as cash or central bank reserves. Meaning et al. (2018) argue that it would be less practical if there is a (flexible) exchange rate operated between cash and CBDC because it means that “the economy would be operating with two distinct fiat currencies simultaneously, albeit with a managed exchange rate” (p. 5).
- *Account- or token-based.* An account-based design emphasizes that the users of CBDC have registered accounts in the central bank and the transactions are done by the central bank using a debit-credit mechanism (debiting the payer’s account and crediting the payee’s account). Therefore, an account-based CBDC does not allow anonymous transactions. On the other hand, a token-based design does not require the CBDC holders to be registered in the central bank. Transactions can be done in peer-to-peer and anonymous mechanism without the involvement of the central bank. A token-based CBDC is similar with cash.
- *Cryptocurrency or not cryptocurrency.* From the technology perspective, CBDC can be designed using the underlying technology of cryptocurrencies, i.e., distributed ledger technology (DLT). However, this technology has some challenges, such as immaturity, consumes a high amount of energy, inefficient, and prone to several security challenges (Norges Bank, 2018). CBDC can also be designed centrally using the more mature technology that underlies existing central bank real-time gross settlement systems (Meaning et al., 2018).

Figure 5 summarizes above parameters of CBDC and provides comparison with other money-like assets (Meaning et al., 2018), while Figure 6 describes a Venn-diagram called the Money Flower (CPMI, 2018)²⁰ that presents a taxonomy of money which includes four main properties: 1) the money issuer (central bank or non-central bank); 2) the money form (digital or physical); 3) the accessibility (universally or restricted); and 4) the technology (account-based or token-based).

	CBDC	Reserves	Central Bank Notes	Deposits	Bitcoin	Ether ^a
Liability of the central bank	✓	✓	✓	x	x	x
Electronic	✓	✓	x	✓	✓	✓
Universally accessible	?	x	✓	✓	✓	✓
Interest bearing	?	?	x	?	x	x
Trades at par ^b	?	✓	✓	✓	x	x
Cryptocurrency	?	x	x	x	✓	✓
Token or account based	?	A	T	A	T	A

^aWe have taken Bitcoin and Ether as the best known examples of privately-issued cryptocurrency. The characteristics shown are also accurate for the majority of cryptocurrencies, although the economic and technological design of different cryptocurrencies can vary significantly.

^bTrades at par with other central bank liabilities

Figure 5 List of Characteristics of CBDC and Other Money-Like Assets (Meaning et al., 2018)

²⁰ Based on the Money Flower presented in Bech & Garratt (2017).

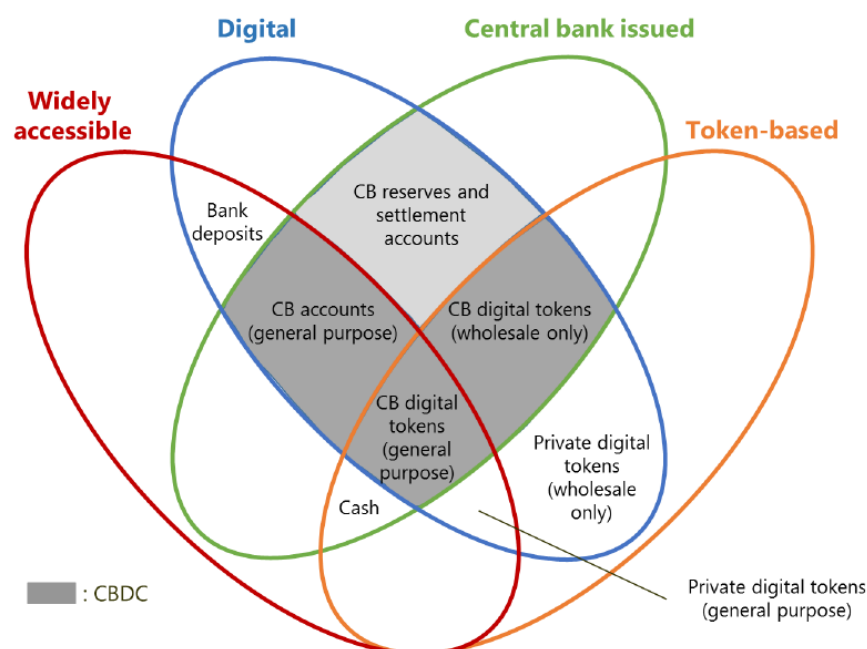


Figure 6 A Money Flower: A General Taxonomy of Money (CPMI, 2018)

2.2 Transaction Cost Economics (TCE) Framework

Williamson (2005) explains that transaction cost economics or TCE tries to understand complex economic organization by joining the law, economics, and organizational theory. TCE has different perspective with neoclassical economics; neoclassical economics is concerned with price and output and sees the firm as a production function, while TCE “is concerned with the allocation of economic activity across alternative modes of organization (markets, firms, bureaus, etc.)” (Williamson, 2005, p.41), and sees the firm as governance structure (organizational construction). In TCE, transaction is the basic unit of analysis, and TCE focuses on the transaction cost economizing of running the economic system (Williamson, 1981a, 1981b).

Williamson (1981b, 1989) explains that TCE maintains the importance of *behavioral assumption*, which is a tendency of human to maximize their profitability and utility. There are two behavioral assumptions on which TCE relies, i.e., bounded rationality and opportunism (Williamson, 1981b). Bounded rationality explains human as “organization man”, not as “economic man” (Williamson, 1981a). As an “economic man”, human tends to have hyperrationality, while as an “organization man”, human has limited analytical and data-processing capability. However, bounded rationality does not mean irrationality. Instead, human is “intendedly rational” (Williamson, 1981a, 1981b, 1989). Teo & Yu (2005, p.452) provides an example related to bounded rationality: “no matter how knowledgeable managers are, they are not able to accurately consider all possible alternative courses of action. Meanwhile, they also have to take into account the unpredictable reactions of their competitors. Therefore, reaching an optimal decision may be difficult. As the result, managers tend to satisfy most, rather than all, conditions when making decisions.” On the other hand, opportunism is a self-interest-seeking that makes allowance for guile (Williamson, 1981a). Or as explained by Teo & Yu (2005, p.452), “... some people may not be entirely honest and truthful about their intentions some of the time, or they may attempt to make use of unexpected circumstances that give them the chance to make the most off another party in a transaction.” Both of these behavioral assumptions explain human’s profit maximization tendency despite their limitation.

Behavioral assumptions can be seen as human factors of transaction cost theory. Williamson (1981b) then explains three critical dimensions to characterize transactions (transactional factors), i.e., transaction frequency, uncertainty, and asset specificity. Teo & Yu (2005) argues that transaction frequency has a very strong effect on transaction cost. They provide an example in which it is more economically rational for a firm to outsource its infrequent needs to other firms that can fulfill the needs than build an internal capability. Related to uncertainty, Teo & Yu (2005) argues that it causes difficulty in predicting possible events that may occur during transactions. For example, “... there is uncertainty in the transaction when one cannot be sure that the other party will not go out of business or try to renegotiate the contract at some future time during the life of the contract” (Teo & Yu, 2005, p.453). In this case, the transacting parties need to safeguard the contract to protect themselves which eventually will raise the costs of monitoring and enforcing a contract. In other words, uncertainty will increase transaction cost. Lastly, asset specificity refers “to the degree to which an asset can be redeployed to alternative uses and by alternative users without sacrifice of productive value” (Williamson, 1989, p.142). That means the transaction cost will increase as the transacting parties make greater asset-specific investments (Teo & Yu, 2005).

2.3 Conceptual Model

Transaction costs are examined by identifying factors related to the three transactional dimensions of the transaction cost economics (TCE) framework, i.e., uncertainty, transaction frequency, and asset specificity. Figure 7 shows the core concept of the TCE framework which describes the three transactional dimensions used to characterize the transaction costs.

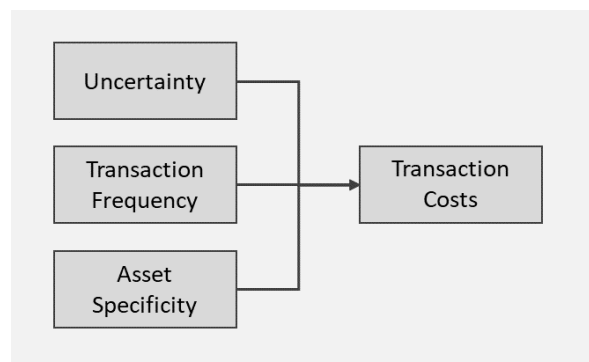


Figure 7 Transactional Dimensions of TCE

In this research, the core concept of transactional dimensions of TCE will be applied to the evaluation process of the CBDC design options. As has been mentioned in Section 1.5, each of the transactional dimension will be operationalized to make it more specific and applicable in the context of CBDC. Figure 8 describes the conceptual model used in this research. The explanation of the conceptual model can be found in the following sub-sections.

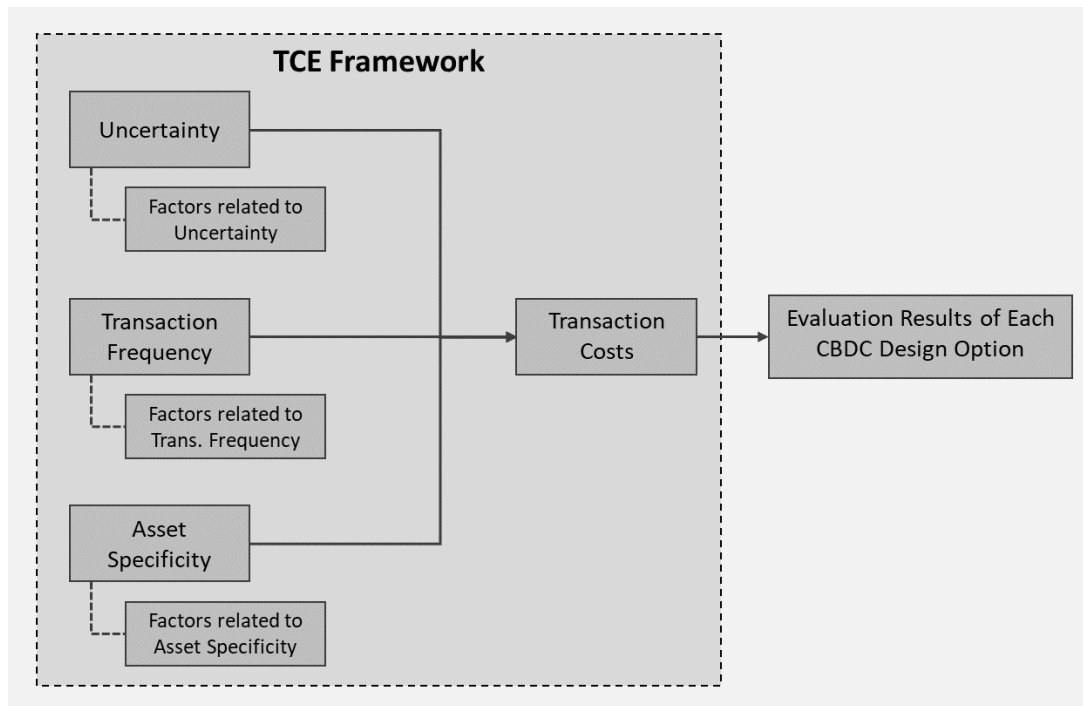


Figure 8 Conceptual Model of This Research

2.3.1 Uncertainty

Teo & Yu (2005) argues that uncertainty may be caused by bounded rationality, information asymmetry, and opportunism. In the context of CBDC, uncertainty may be caused by multiple factors, such as the global financial condition and the economic agents' behaviors towards CBDC. Because CBDC is a relatively new phenomenon, there is not much information available and the economic agents may experience difficulties in determining the output of their behaviors under CBDC economy. As a result, due to the high degree of uncertainty, the economic agents may need to perform additional efforts to, for instance, analyze and evaluate the conditions to obtain maximum benefits or efficiency of CBDC, thus increasing their transaction costs.

Among the three transactional dimensions of TCE, uncertainty is considered as critical (Williamson, 1979). Therefore, it is expected that the uncertainty dimension may have the most significant effect on the transaction costs of CBDC design options.

2.3.2 Transaction Frequency

The digital nature of CBDC allows the economic agents to use it in relatively easy ways, thus they can do as many transactions as they want, assuming that they possess proper equipment to use it. For example, in the case of universally accessible CBDC, as long as the central bank (or other third parties that assigned by the central bank) has the technology with proper computing capacity, the frequency of transactions (or settlements) would not be a concern. Therefore, in the context of CBDC, it is expected that the number of transactions will not have significant effects on the economic agents. This is in accordance with the argument of Williamson (1979), which is “frequency matters is at least plausible” (p. 239).

2.3.3 Asset Specificity

Williamson (1981a) explains that asset specificity can arise in the form of site specificity, physical asset specificity, and human asset specificity. Site specificity represents the necessity of locating stations (in manufacturing) “to economize on inventory and transportation expenses” (p. 555). Physical asset specificity represents the necessity to deploy specific equipment “to produce a component” (Williamson, 1981a, p. 555). And finally, human asset specificity represents the specificity that “arises from learning by doing” (Williamson, 1981a, p. 555).

In the context of CBDC, since it will be produced in digital form, site specificity would have the most insignificant effect on the transaction costs. Instead, physical asset and human asset specificities would be the factors that play the most significant role in determining the transaction costs. As explained in Sub-section 2.3.2, the economic agents are required to possess proper equipment to access CBDC. Therefore, they need to make specific investments on physical equipment (e.g., computing power to process or to clear the transactions and to monitor the movement of CBDC in a real-time manner) as well as on human resources (e.g., need to deploy specific task force or department to analyze and monitor CBDC-related problems). Thus, it is expected that the more specific the investment made in relation to CBDC, the higher the transaction costs.

3 Chapter 3 – Methodology

As showed in Table 1, the literature review process was then followed by the Semi-structured Interview Preparation, Execution, and Coding phase and Data Analysis and Interpretation phase. This chapter explains those two main phases.

3.1 Semi-Structured Interview Preparation and Execution

3.1.1 Interview Protocol Design

Castillo-Montoya (2016) explains that an interview protocol is an instrument used by the researcher to ask questions to gain specific information related to the aims of the research. In its concrete form, an interview protocol is a guide containing a list of questions that will be asked during the interview. Interview protocol serves several functions. First, it enables the researcher to perform the same basic lines of inquiry for all interview participants or interviewees (*Interview Protocol*, n.d.), so it ensures that the context of the asked questions is standardized for all interviewees. Second, the interview protocol helps the researcher to perform more systematic and comprehensive interview sessions (*Interview Protocol*, n.d.) within the limited or available time. Third, Castillo-Montoya (2016) adds that an interview protocol also serves as an instrument for conversation, thus making the interview as an inquiry-based conversation. The researcher is able to develop the interview sessions as more engaging two-way communications while stay focused on and relevant to the topics and the aims of the research.

The interview protocol established in this research was based on the Interview Protocol Refinement (IPR) framework introduced by Castillo-Montoya (2016). This framework consists of four phases as follows.

1. Phase 1: aligning interview questions with research questions. The main activity in this phase is mapping the interview questions with the research questions, ensuring that there are no gaps between the goals of the research and the questions that are being asked.
2. Phase 2: constructing an inquiry-based conversation. The main activity in this phase is developing list of questions that promotes a conversation instead of just asking the research questions directly to the interviewees.
3. Phase 3: receiving feedback. The main activity in this phase is obtaining feedback on the established interview protocol to increase its reliability as a research instrument.
4. Phase 4: piloting the interview protocol. The main activity in this phase is performing interview sessions using the established interview protocol with the people who share similar characteristics of the actual interviewees.

However, this research used a modified version of Interview Protocol Refinement (IPR) framework in which the phases were re-structured and modified in order to fit with the research objectives, the research questions, and the conceptual model. The phases are explained in the following sub-sections.

3.1.1.1 Phase 1: Determining the Scopes of Interview Questions

In this phase, the high-level scopes of interview questions were determined based on the sub-research questions and the literature review aspects. This process was important to establish initial contexts and limit the scopes of the whole interview questions and to ensure that each question provides a contribution to answering the research questions in the most effective ways (e.g., relevant and answerable). Table 2 exhibits the mapping between the sub-research questions, the related aspects within the literature review, and the defined scopes of the interview questions.

Table 2 Mapping of the Sub-Research Questions, Conceptual Model Aspects, and Interview Question Scopes

Sub-RQ	Literature Review Aspect	Interview Question Scope
Sub-RQ1: <i>What are the possible CBDC design options and their characteristics?</i>	CBDC attributes based on: • Meaning et al. (2018) • CPMI (2018)	Defining CBDC
Sub-RQ2: <i>Which are the impacted economic agents in each possible CBDC design option?</i>	-	Determining Impacted Economic Agents
Sub-RQ3: <i>What are the factors associated with the transactional dimensions of TCE that impact each economic agent in each CBDC design option?</i>	TCE framework: Transaction Cost	Estimating Efforts for Each Impacted Agents
	TCE framework: Uncertainty	Transaction Cost Factor – Uncertainty
	TCE framework: Transaction frequency	Transaction Cost Factor – Transaction Frequency
	TCE framework: Asset specificity	Transaction Cost Factor – Asset Specificity

3.1.1.2 Phase 2: Developing and Mapping of Interview Questions

There were two processes performed in this phase. First, the interview questions were developed based on the interview question scopes. Second, all interview questions were mapped back to the sub-research questions to ensure that all research questions (the main research question and the sub-research questions) were covered comprehensively by the interview questions. Those processes are explained in the following sub-sections.

3.1.1.2.1 Phase 2.1: Developing Interview Questions

Table 3 exhibits the list of interview questions and the related interview question scope. A question ID is assigned to each interview question.

Table 3 List of Interview Questions

Question Scope	Question ID	Interview Question
Defining CBDC	Q1	Can you please describe or define central bank-issued digital currency (henceforth, CBDC) based on your view?
	Q2	According to you, what are the possible designs of CBDC implementation?
	Q2.1	In which monetary/banking system(s) those designs can be implemented (e.g., full reserve banking, fractional reserve banking, narrow banking, free banking, etc.)?
	Q2.2	Should it be universally accessible (i.e., all economic agents can have access to central bank liabilities)?
	Q2.3	Which function(s) of money that serve primarily (medium of exchange, store of value, or unit of account)?

Question Scope	Question ID	Interview Question
	Q2.4	Should it feature peer-to-peer or multitier payment?
	Q2.5	Should it be anonymous?
	Q2.6	Should it be interest-bearing?
	Q2.7	Should central banks maintain or remove deposit guarantee scheme?
	Q2.8	Should it use distributed ledger (or blockchain) technology or centralized architecture?
	Q2.9	Which design(s) do you prefer and why do you prefer that/those particular design(s)?
Determining Impacted Economic Agents	Q3	<p>In the CBDC design(s) that you prefer, which are the impacted economic agents?</p> <p><i>The interviewee is asked to confirm based on following pre-defined list.</i></p> <ul style="list-style-type: none"> • <i>Households</i> • <i>Non-financial institutions (public and private enterprises that produce goods or provide non-financial services)</i> • <i>Government</i> • <i>Commercial banks and other financial corporations (investment banks, pension funds, insurance corporations)</i> • <i>Central bank</i> • <i>Other economic agents</i>
Estimating Efforts for Each Impacted Agents	Q4.1	For a central bank, what are the processes involved required in introducing or implementing CBDC economy during decision-making phase, implementation phase, and post-implementation phase?
	Q4.2	What are the specific resources used in each process or phase?
Transaction Cost Factor – Uncertainty	Q4.3	Which factors or risks cannot be quantified and/or controlled during decision-making phase, implementation phase, and post-implementation phase??
	Q4.4	Which factors lead to uncertainty of the output of the process or phase?
Transaction Cost Factor – Asset Specificity	Q4.5	Which factors related to the specificity of deployed resources in the process or phase (i.e., technology and human resources)?
Transaction Cost Factor – Transaction Frequency	Q4.6	Will the frequency of transactions using CBDC incur significant efforts for central banks in maintaining macroeconomic stability through monetary policy?
Estimating Efforts for Each Impacted Agents	Q5.1	For commercial banks, what are the financial products and services that may be affected?
	Q5.2	Which aspects of financial products and services that may be affected?

Question Scope	Question ID	Interview Question
Transaction Cost Factor – Uncertainty	Q5.3	Which factors or risks cannot be quantified and/or controlled that may lead to the uncertainty behaviors of financial products and services?
Transaction Cost Factor – Asset Specificity	Q5.4	Do banks need to deploy specific resources to comply with the CBDC economy (e.g., new technologies, human resources, etc.)?
Transaction Cost Factor – Transaction Frequency	Q5.5	Will the frequency of transactions using CBDC incur significant efforts for commercial banks in providing financial products and services to their customers?
Estimating Efforts for Each Impacted Agents	Q5.6	Do commercial banks need to adjust their functions or roles in the economy?
	Q5.7	To what extent CBDC affects interest expenses and non-interest expenses?
Transaction Cost Factor – Uncertainty	Q5.8	Which factors or risks cannot be quantified and/or controlled that may affect interest expenses and non-interest expenses?
Transaction Cost Factor – Transaction Frequency	Q5.9	Will the frequency of transactions using CBDC incur additional interest and non-interest expenses?
Estimating Transaction Costs for Each Impacted Agents	Q5.10	Are there any other aspects of commercial banks and other financial institutions that may be affected by CBDC during transition period and after implementation?
Estimating Transaction Costs for Each Impacted Agents	Q6.1	For government, what are the impacts of CBDC economy to the fiscal policy (tax revenues and government spending)?
	Q6.2	To what extent the fiscal policy is affected?
Transaction Cost Factor – Uncertainty	Q6.3	Which factors or risks cannot be quantified and/or controlled related to the fiscal policy?
Transaction Cost Factor – Asset Specificity	Q6.4	Do governments need to deploy specific resources to adapt with the CBDC economy (e.g., new technologies, human resources, etc.)?
Transaction Cost Factor – Transaction Frequency	Q6.5	Will the frequency of transactions using CBDC incur significant efforts for government in maintaining macroeconomic economy stability through fiscal policy?

Question Scope	Question ID	Interview Question
Estimating Efforts for Each Impacted Agents	Q7.1	What are the impacts of CBDC economy to household income?
	Q7.2	To what extent households' income is affected?
Transaction Cost Factor – Uncertainty	Q7.3	Which factors lead to uncertainty of households' income?
Transaction Cost Factor – Asset Specificity	Q7.4	Do households and non-financial corporations need to deploy specific resources to reap benefits of or adapt to CBDC economy?
Estimating Efforts for Each Impacted Agents	Q7.5	To what extent households' consumption is affected?
	Q7.6	Which factors lead to uncertainty of households' consumption behaviors?

3.1.1.2.2 Phase 2.2: Mapping Interview Questions to Research Questions

Table 4 exhibits the mapping of the interview questions and the sub-research questions. The covered sub-research questions are marked with “X”. Table 4 shows that all interview questions can be mapped back to the sub-research questions, so it is expected that all the interview questions can provide contribution in answering the main research question by addressing the problems defined in the sub-research questions.

Table 4 Mapping of Interview Questions and Sub-Research Questions

Question ID	Sub-RQ1	Sub-RQ2	Sub-RQ3
Q1	X		
Q2	X		
Q2.1	X		
Q2.2	X		
Q2.3	X		
Q2.4	X		
Q2.5	X		
Q2.6	X		
Q2.7	X		
Q2.8	X		
Q2.9	X		
Q3		X	
Q4.1			X
Q4.2			X
Q4.3			X
Q4.4			X

Question ID	Sub-RQ1	Sub-RQ2	Sub-RQ3
Q4.5			X
Q4.6			X
Q5.1			X
Q5.2			X
Q5.3			X
Q5.4			X
Q5.5			X
Q5.6			X
Q5.7			X
Q5.8			X
Q5.9			X
Q5.10			X
Q6.1			X
Q6.2			X
Q6.3			X
Q6.4			X
Q6.5			X
Q7.1			X
Q7.2			X
Q7.3			X
Q7.4			X
Q7.5			X
Q7.6			X

3.1.1.3 Phase 3: Conducting Pilot Interviews and Obtaining Feedbacks

In this phase, the established interview protocol was brought to pilot interview sessions so that it could be tested directly under real (not simulated) interview sessions. Two interviewees for pilot interview sessions were selected randomly. The tested aspects and their parameters are shown in Table 5 and the selected interviewees to participate in the pilot interview sessions can be seen in Table 7.

Table 5 The Tested Aspects of the Interview Protocol and the Feedbacks from the Interviewees

Interview Protocol Aspects	Tested Parameters	Feedback
Interview Protocol Structure	The questions are logically structured (using top-down approach)	Yes.
	The questions are easy to understand	Yes.
	The questions can be discussed within 60 minutes time limit	The questions may be too many for some interviewees, so the interviewer needs to be able to manage the interview so that all questions can be covered.

Interview Protocol Aspects	Tested Parameters	Feedback
Relevancy	The questions are relevant with current discussions of CBDC	Yes. One question related to deposit guarantee scheme (Q2.7 in Table 3) was added, as suggested by one of the interviewees.
	The questions are relevant to answer the research questions	Yes.
	All questions are needed (Castillo-Montoya, 2016)	Yes.

3.1.2 Participants Selection and Invitation

3.1.2.1 Criteria for Participants

The participants or interviewees of this research were experts with various professional backgrounds. To obtain as diverse point of view as possible, this research involved experts from central banks, commercial banks, regulatory bodies, and relevant NGOs. Because CBDC is considered as a new topic and the literature “remains in its relative infancy with consensus around some fundamental issues only slowly beginning to form” (Meaning et al., 2018, p. 2), the population of the experts is relatively small. Therefore, it is important to be able to identify the most suitable population for this research.

There were two steps in determining the eligible participants for this research. The first step was to determine the initial population of experts by performing a thorough literature review on CBDC designs and implementation options. The literature review process showed that two major central banks in Europe, which were the Bank of England (United Kingdom) and the Sveriges Riksbank (Sweden), had performed more significant and extensive studies related to CBDC compared to other European central banks. Table 6 exhibits the recent literature by the Bank of England and the Sveriges Riksbank on CBDC.

Table 6 Recent Literature by the Bank of England and the Sveriges Riksbank on CBDC

Central Bank	Author(s) and Year	Title	Topics
Bank of England	John Barrdear & Michael Kumhof (2016)	The macroeconomics of central bank issued digital currencies	Macroeconomic consequences of CBDC issuance based on simulation using DSGE model
	Jack Meaning, Ben Dyson, James Barker, & Emily Clayton (2018)	Broadening narrow money: monetary policy with a central bank digital currency	Potential impacts of CBDC on the various stages of monetary transmission mechanism (MTM)
	Michael Kumhof & Clare Noone (2018)	Central bank digital currencies — design principles and balance sheet implications	The impact of three access models of CBDC, namely <ul style="list-style-type: none"> • Financial Institutions Access Model (Model FI),

Central Bank	Author(s) and Year	Title	Topics
			<ul style="list-style-type: none"> • Economy-Wide Access Model (Model EW), and • Financial Institutions Plus CBDC Backed Narrow Bank Access Model (Model FI+), on the balance sheets of the impacted sectors, as well as four core principles of CBDC implementation
Sveriges Riksbank	September 2017	The Riksbank's e-krona project – Report 1	Report of investigation on the possibility of introducing e-krona that consists of several aspects: <ul style="list-style-type: none"> • the motivations to introduce e-krona • possible designs of e-krona • potential consequences of e-krona on the Riksbank's balance sheet, monetary policy, financial stability, and market participants • the legal aspects of e-krona
	December 2017	The Riksbank's e-krona project – Action plan for 2018	The roadmap of e-krona project, including the risk management, resource requirements, and project organization

Based on that consideration, several authors from above literature were selected to be the candidate of eligible experts to be interviewed. The authors were selected based on background checking process done by the researcher, which utilizes the Google search engine and the LinkedIn profiles of the authors. The search results and the LinkedIn profiles should display works (published papers or ongoing research) and positions related to digital currency topics. In addition, since this research was mainly based in the Netherlands, De Nederlandsche Bank (DNB, the Dutch central bank) was also of interest in this research. Eligible experts at the DNB were obtained from the list of members of the Committee on Payments and Markets Infrastructures (CPMI) of the Bank for International Settlements (BIS). The same background checking process was also applied to this expert group. In summary, this first step provided a list of experts from the European central bank with interests or professional experiences on digital currency-related topics.

The second step involved a snowball sampling technique in obtaining other experts from different backgrounds that share similar interest or expertise on CBDC. This snowball sampling provided a list

of experts from a large commercial bank in a Eurozone country, regulatory bodies in a Eurozone country, and relevant NGOs, which were the organization members of International Movement for Monetary Reform (IMMR).

3.1.2.2 List of Experts

Table 7 exhibits the list of invited experts²¹ with their details (area of expertise or interest, affiliation, and position), as well as their invitation status code. The participants were invited using email. The meaning of the invitation status code is as follows.

- A: accepted the invitation
- A_P: accepted the invitation and was selected for pilot interview sessions
- B: ignored the invitation (no updates or no replies)
- C: rejected the invitation

Table 7 List of Invited Experts

Group	Expert Code	Area of Expertise or Interest	Affiliation ²²	Position	Invitation Status
Central Bank	BoE-1	Economics of Money and Banking, Monetary Policy, Fiscal Policy, International Finance, Economics of Exhaustible Resources	Bank of England	Senior Research Advisor	A
	BoE-2	Digital Currencies	Bank of England	Researcher	B
	BoE-3	Digital Currencies	Bank of England	Digital Currencies Team	A
	RBA	Digital Currencies, Payments Policy	Reserve Bank of Australia	Senior Manager	C
	DNB-1	Banking & Finance, Monetary Economics	DNB	Senior Expert Market Intelligence	A _P
	DNB-2		DNB	Policy Advisor	A
	DNB-3	Technological innovations, especially blockchains and DLTs, crypto- and	DNB	Policy advisor	C

²¹ The names of the experts are not published due to privacy reasons. Instead, the names are converted into expert code based on their respective affiliation.

²² The listed affiliation is the affiliation of the expert when the interview was conducted.

Group	Expert Code	Area of Expertise or Interest	Affiliation ²²	Position	Invitation Status
		digital currencies, ICOs			
Commercial Bank	CmB	Euro Area economy, the interplay between finance and economics and regulatory economics	A large commercial bank in a Eurozone country	Principal Economist	A
Regulatory Bodies	MoF		Ministry of Finance in a Eurozone country	Policy Economist (now Banking Supervision Policy)	A
	FMA-1		Financial Market Authority in a Eurozone country	Supervisor	A
	FMA-2		Financial Market Authority in a Eurozone country		A
NGO	PP IMMR-1		A European member of International Movement for Monetary Reform (IMMR)	Chairman	A _P
	OG IMMR-2		A European member of International Movement for Monetary Reform (IMMR)	Advisor	A
	PM IMMR-3		A European member of International Movement for Monetary	Head of Europe	C

Group	Expert Code	Area of Expertise or Interest	Affiliation ²²	Position	Invitation Status
			Reform (IMMR)		
Academics	UCSB	Economic Theory, Behavioral Economics, Monetary Theory	Department of Economics University of California-Santa Barbara (UCSB)	Professor of Economics	C
	RSM	Financial Stability, Financial System Architecture	Department of Finance Rotterdam School of Management (RSM)	Professor of Banking and Finance	C
	TUD	Macroeconomics, Economics & Finance, Economic Growth, Structural Change and Distribution	Faculty of Technology, Policy and Management of TU Delft	Senior Researcher	B

3.1.3 Interview Sessions

When the invited experts replied the invitation emails, the date, time, and place for the interview were decided according to the preferences of the experts. The interview sessions were done in direct (i.e., face-to-face) and indirect (i.e., via phone and video calls) ways, depending on the expert's location. Table 8 exhibits the list of experts that were interviewed as well as the interview date and the interview method used for each expert.

Table 8 List of Interviewed Experts and the Interview Method and Date

Expert Code	Interview Method	Interview Date
BoE-1	Phone Call	11-Jul-2018
BoE-3	Phone Call	24-Jul-2018
DNB-1	Face-to-Face	4-Jul-2018
DNB-2	Face-to-Face	18-Jul-2018
CmB	Face-to-Face	13-Aug-2018
MoF	Face-to-Face	17-Aug-2018
FMA-1	Face-to-Face	18-Jul-2018
FMA-2	Face-to-Face	2-Aug-2018
IMMR-1	Skype Video Call	9-Jul-2018
IMMR-2	Face-to-Face	15-Aug-2018

3.2 Coding and Analysis

3.2.1 Interview Transcribing

The interview sessions were recorded, and then the interview recordings were transcribed using the assistance of an Automatic Speech Recognition (ASR) tool called Speechmatics (<https://www.speechmatics.com/>). To increase the accuracy of the interview transcriptions, a refining process was done by manually synchronizing the interview recordings and the generated interview transcriptions.

Out of 10 interview recordings, nine recordings were successfully transcribed, and one recording was not transcribed since the recording file was corrupted and could not be recovered. Table 9 exhibits the recording status for all interview sessions (OK: successfully transcribed and analyzed; Not OK: could not be transcribed and analyzed).

Table 9 Recording Status of All Interview Sessions

Interview Session	Recording Status
BoE-1	OK
BoE-3	Not OK
DNB-1	OK
DNB-2	OK
CmB	OK
MoF	OK
FMA-1	OK
FMA-2	OK
IMMR-1	OK
IMMR-2	OK

3.2.2 Interview Coding

The coding process was done electronically using ATLAS.ti 8 for Windows, one of the computer-assisted qualitative data analysis software (CAQDAS). The coding process was done in two cycles based on the coding manual explained by Saldaña (2009). The following sub-sections explain the coding process using ATLAS.ti 8 for Windows.

3.2.2.1 First Cycle Coding

Saldaña (2009) explains the First Cycle processes “happen during the initial coding of data” (p. 45) and can be done using several coding methods. First Cycle enables the researcher to gain an initial understanding of the collected data, such as the general theme or idea of the data. In this research, the First Cycle was done using the combination of Descriptive Coding and Provisional Coding. Descriptive Coding summarizes the basic topic of large parts in the interview transcriptions into a word or short phrase (Saldaña, 2009). Provisional Coding is a coding method where the codes are initially determined by the researcher. The codes “can be developed from anticipated categories or types of responses/actions that may arise in the data yet to be collected” based on “literature reviews related to the study, the study's conceptual framework and research questions, previous research findings, pilot study fieldwork, the researcher's previous knowledge and experiences (experiential data), and researcher-formulated hypotheses or hunches” (Saldaña, 2009, p. 120).

In this research, some of the codes were predetermined based on the possible attributes of CBDC as explained in Sub-section 2.1.4.2. Then, the interview transcriptions were thoroughly read and coded using Descriptive Coding. The list of the predetermined codes used in the First Cycle can be seen in Appendix B–1.1 Predetermined Codes and the list of all used codes at the end of the First Cycle (including the predetermined codes), as well as the frequency of their appearances in the whole interview transcriptions, can be seen in Appendix B–1.2 All Codes at the End of the First Cycle.

3.2.2.2 Second Cycle Coding

Second Cycle Coding contains the processes where the coded data from the First Cycle Coding is reorganized and reanalyzed (Saldaña, 2009). The aim of this cycle is “to develop a sense of categorical, thematic, conceptual, and/or theoretical organization” (Saldaña, 2009, p. 149) of the First Cycle codes. There are several coding methods specified by Saldaña, but this research only used one method, which was Pattern Coding. Pattern Coding groups the First Cycle codes into a smaller number of meaningful categories or themes. In this research, Pattern Coding consisted of reanalysis and refinement processes of the First Cycle codes as follows.

- Merging. The codes represented parts of the interview transcriptions with the same contexts were merged.
- Cleaning. Redundant or duplicated codes were deleted. Also, meaningless codes that could not or might not contribute to further analysis were deleted.
- Renaming. Several codes were renamed to represent the coded data better.
- Grouping. Several codes with the same patterns were grouped to establish more meaningful categories.

In this Second Cycle, Networks of codes were also built in Atlas.ti 8 so that the relationships of ideas contained in the interview transcriptions can be displayed and understood for further analysis. A Network in Atlas.ti 8 consists of three important elements as follows.

- Nodes. A node is “any object that is displayed in a Network” (Frieze, 2018, p. 16). In this research, a node represents a code.
- Relations. A relation is a “link prototypes used to create a link between two codes” (Frieze, 2018, p. 16). In this research, relations were used to describe the relationship between codes. For example, relation “is impacted in” was used to describe that the economic agent is impacted in the particular CBDC design: agent: central bank “is impacted in” #design options: retail CBDC.
- Links. Frieze (2018) explains that “links are usually drawn as lines between the connected nodes in graphical presentations of networks” (p. 185).

Figure 9 shows a Network describing the relationship of four nodes: agent: central bank, #design options: wholesale CBDC, #design options: retail CBDC, and #design options: full-reserve depository banks. In this context, the relation used is “is impacted in”, to represent that the central bank is impacted in three CBDC design options: wholesale CBDC, retail CBDC, and full-reserve depository banks.

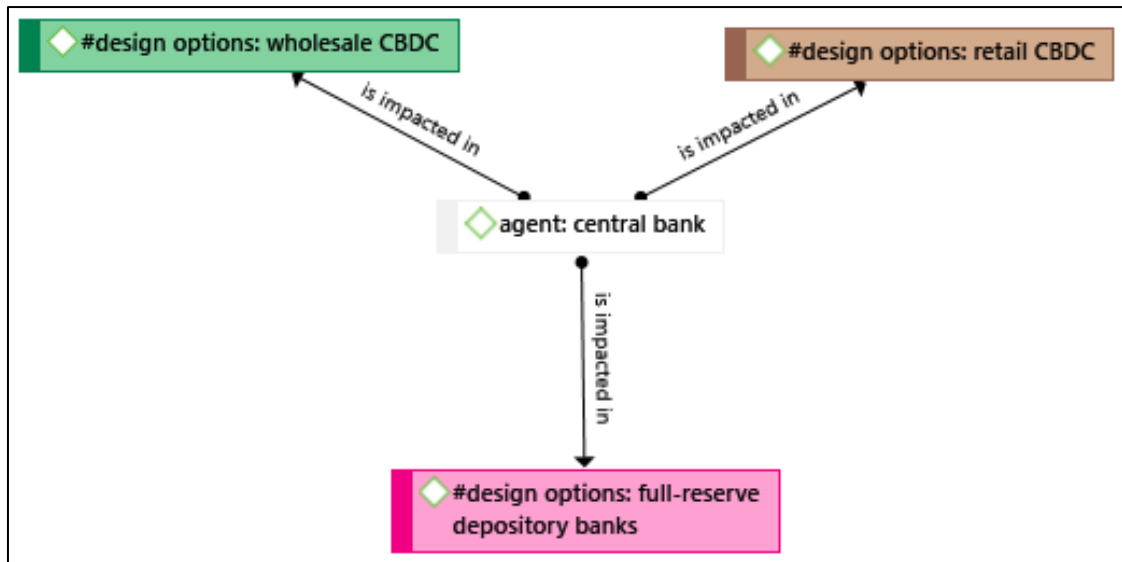


Figure 9 A Network of Nodes in Atlas.ti 8 for Windows

4 Chapter 4 – Results and Analysis

This chapter presents and discusses the results and findings of the whole processes in this research. The results of the interview sessions can be divided into four main parts: 1) the CBDC design options and their respective characteristics; 2) the impacted economic agents; 3) the factors of TCE transactional dimensions; and 4) the characterized transaction costs. Each of the part answers one of the sub-research question.

4.1 CBDC Design Options

This section answers the first sub-research question as follows.

Sub-RQ1: What are the possible CBDC design options and their characteristics?

Based on the analyzed interview results, there are three main design options for CBDC as shown in Figure 10 and Table 10. Figure 10 describes the established network in Atlas.ti 8 and Table 10 exhibits the CBDC design options as well as the experts that were focusing on the design options during the interview sessions²³.

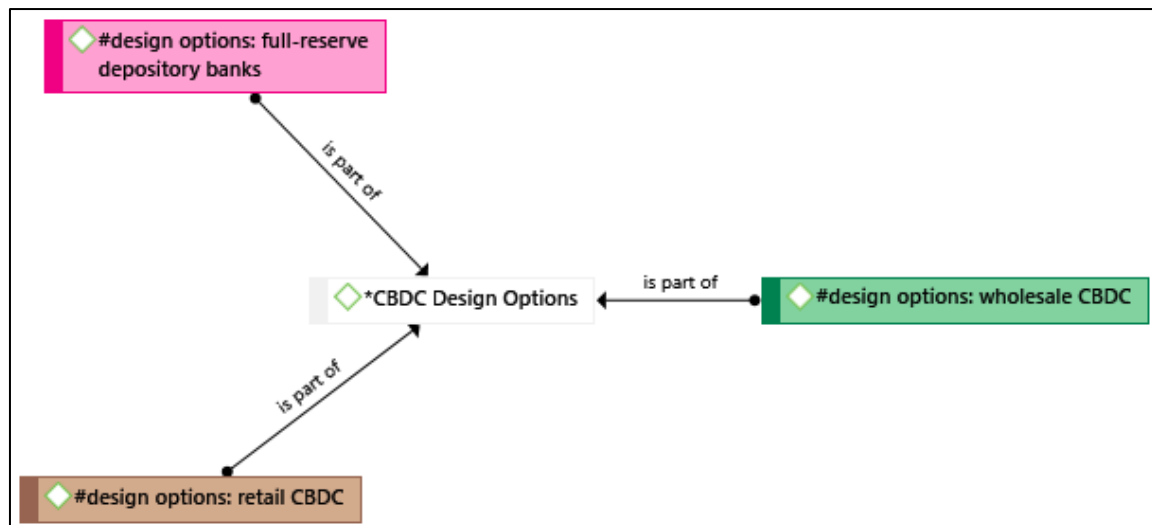


Figure 10 CBDC Design Options

Table 10 CBDC Design Options Explained by the Experts

CBDC Design Options	Explained By
Retail CBDC	BoE-1
	DNB-1
	CmB
	FMA-2
	MoF
	IMMR-1
	IMMR-2

²³ This table does not specify the preferred CBDC design option of the experts. In other words, although an expert focused on a particular CBDC design option, that does not mean that the expert preferred that design option to other design options.

CBDC Design Options	Explained By
Wholesale CBDC	DNB-2
Full-Reserve Depository Banks	FMA-1

Table 11 summarizes all the CBDC design options and the characteristics of each CBDC design option according to the experts.

Table 11 Basic Characteristics of Each CBDC Design Option

Attributes	Retail CBDC	Wholesale CBDC	Full-Reserve Depository Banks
Accessibility	Universal	Limited to wholesale market participants	Universal, but limited to residents
Anonymous	No	No	No
Interest-bearing	Yes/No	Yes	No
Primary Money Function	<ul style="list-style-type: none"> • Store of value • Means of payment • Medium of exchange 	<ul style="list-style-type: none"> • Store of value • Means of payment 	Medium of exchange
Facilitates Peer-to-Peer	No	No	No
Employ DLT	No	No	No
Should Deposit Guarantee Scheme Removed?	Yes, gradually/No	No	Yes, gradually
Impacted Economic Agents	<ul style="list-style-type: none"> • Central bank • Commercial banks • Other financial institutions • Government • Households • Non-financial institutions 	<ul style="list-style-type: none"> • Central bank • Commercial banks • Other financial institutions • Government 	<ul style="list-style-type: none"> • Central bank • Commercial banks • Other financial institutions • Government

The detailed explanations of each attribute of the CBDC design option according to the experts²⁴ are presented in the following sub-sections.

4.1.1 Accessibility

In Retail CBDC design option, the access of CBDC is opened for the general public (universally accessible). The main concept of Retail CBDC is widening access of central bank's money to the all economic agents. This means that the central bank's balance sheet can be accessed not only by the commercial banks, but also by other financial institutions, the government, and even households and

²⁴ The explanations are based on the interview sessions. Other literature published by central banks may provide more detailed or even different explanations.

non-financial institutions. However, this design option has higher risks compared to other design options due to its broader economic coverage.

On the other hand, Wholesale CBDC design option is similar with current's central bank reserves where only the commercial banks are allowed to have direct accounts in the central bank. However, in this design option, not only the commercial banks but also other financial institutions and other wholesale money market participants can access the central bank's balance sheet.

The third design option is Full-reserve Depository Banks (FrDB CBDC) design option. This is a design option in which there is one additional entity called depository bank is required to operate under a full-reserve policy. This means that the claims are not on the central bank's balance sheet, but on the depository banks'. All claims should be 100% backed by central bank liabilities or central bank reserves. Depository banks will have different functions with the commercial banks in which the depository banks will offer depository and payment services while the commercial banks will focus more on credit and investment activities. This accessibility of this type of CBDC is similar to the Retail CBDC's, but only limited to the residents. FrDB CBDC should not be accessible to foreigners.

4.1.2 Anonymity

There were two options asked for CBDC anonymity during the interview sessions, i.e., anonymous and non-anonymous. However, most of the experts emphasized the importance of the non-anonymous version of Retail CBDC. This means that all the economic agents that want to access CBDC should have direct accounts in the central bank, thus this would be account-based CBDC, not token-based CBDC²⁵. By implementing account-based CBDC, it is expected that the central bank would be able to control the payment systems and thus affecting all the transactions done in the economy. Also, as explained by one of the experts, account-based CBDC could reduce the usage of money for illicit activities (as what happens with the physical cash), such as terrorism financing, tax evasion, and tax fraud. In the end, account-based CBDC will benefit the government (e.g., less law enforcement costs and more tax revenues).

Regarding the account management aspect, the central bank could create and handle all of the retail accounts directly or give mandates to the commercial banks (which have already had direct accounts in the central bank) to manage the retail accounts. The latter incurs less efforts than the former because the central bank does not need to do customer-specific activities such as KYC (know your customer). One of the experts described the latter solution as shown in Figure 11.

Although account-based CBDC might provide benefits for the government or regulator, there is also privacy issue that needs to be addressed. However, this issue was not discussed in detail during interview sessions.

²⁵ Unlike account-based CBDC, a token-based CBDC can facilitate anonymous transactions. However, a token-based CBDC "can, in principle, be designed to provide different degrees of anonymity in a way that is similar to private digital tokens" (BIS, 2018, p.6).

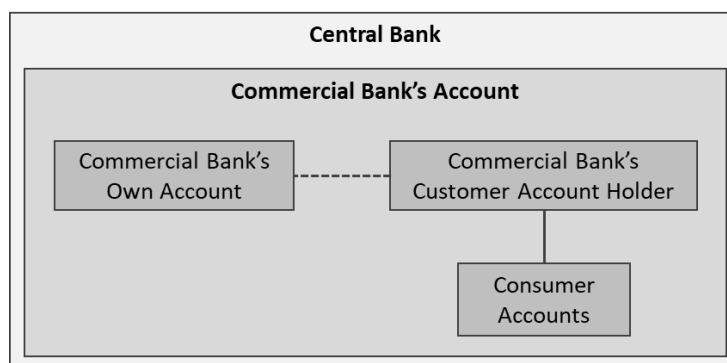


Figure 11 Idea of Customer Account Management in Retail CBDC

4.1.3 Interest-bearing

This is the most interesting aspect in the interview sessions because some of the experts suggested that CBDC should be interest-bearing, while the others suggested it to be non-interest-bearing. If the central bank puts interest on CBDC, then the central bank would have additional tools to manage supply and demand of the CBDC. However, as explained by some of the experts, if there is no interest in CBDC, then the central bank could implement quantity policy instead of interest policy. It is important to leave the market to adjust the price to the quantity, not the other way around.

4.1.4 Primary Money Function

As explained in Sub-section 2.1.1, there are several functions of money: as a medium of exchange, a measure of value (or unit of account), a store of value, and a means of payment. Based on the interview results, there are no dominant answers regarding the function of money that served primarily by CBDC. For Retail CBDC, most of the experts explained that CBDC can be used as the store of value because CBDC could offer another option for non-bank entities (other non-bank financial institutions, households, and non-financial institutions) as the safe way to store their money, because the central bank is much safer than the commercial banks as the central bank cannot go bankrupt. In the Wholesale CBDC, the wholesale money market participants can use CBDC as a risk-free, perfectly liquid instruments that they can use as a means of payment. In addition, if the central bank decides to put a remuneration to attract the money market participants (especially non-bank financial institutions and non-financial institutions) to hold it, CBDC can also be used also as a store of value. Finally, in the FrDB CBDC design option, CBDC will act primarily as a medium of exchange, but it can also serve as a store of value, depending on how the users see the CBDC.

4.1.5 Peer-to-peer Transactions

Because CBDC is one form of digital money, it could facilitate peer-to-peer transactions in which there are no transaction intermediaries required. However, some of the experts suggested that CBDC should not facilitate peer-to-peer, non-anonymous transactions.

4.1.6 Digital Ledger Technology

In terms of its underlying technology, CBDC could utilize digital ledger technology (DLT). However, none of the experts suggested the use of DLT for CBDC. The experts either refused to answer (because they were not experts on this area) or suggested to use centralized technology because the central bank

needs to have full control over the whole CBDC infrastructure. However, one of the experts mentioned the idea of permissioned blockchain, as described by Scorer (2017).

4.1.7 Deposit Guarantee Scheme

During the interview, there was a question that asked (question ID Q2.7, see Table 3): when the central bank introduces CBDD, should central bank maintain or remove deposit guarantee scheme (DGS)? Most of the experts answered yes, because after CBDC is introduced, especially the Retail CBDC, there is no need for DGS. People can save their money in the central bank for safer savings option (probably with less interest payment) or put their money in the commercial banks for riskier savings option (probably with higher interest payment). Therefore, the central bank is not required to guarantee commercial bank deposits. However, DGS should not be removed immediately to reduce the risk of large funds movements from the commercial bank deposits to CBDC. Instead, it should be removed gradually after the CBDC is fully adopted in the economy.

4.1.8 CBDC Issuance and Banking System

This sub-section is not a specific attribute of CBDC. However, the relationship between CBDC issuance and the banking system was asked to the experts in question ID Q2.1 (see Table 3) to explore whether it is possible to introduce CBDC in the current banking system. Most of the experts provided two kinds of answer. First, CBDC could be introduced in the current banking system. In this case, CBDC could be implemented side-by-side with the current fractional reserve banking system. However, other risks might appear, such as the digital bank run where a large number of funds was moved from commercial bank deposits to CBDC. Second, CBDC and banking system are two different concepts. Having a full reserve banking, for example, is basically a completely different issue for central banks.

4.2 Impacted Economic Agents

This section answers the second sub-research question as follows.

Sub-RQ2: Which are the impacted economic agents in each possible CBDC design option?

Based on the answers of the experts, the impacted economic agents and the potential efforts or impacts need to be made for each CBDC design option are shown in Table 12.

Table 12 List of Impacted Economic Agents and their Potential Efforts in Each CBDC Design Option

CBDC Design Options	Impacted Economic Agents	Potential Efforts or Impacts
Retail CBDC	Central bank	<p>Would need to put specialized human resources (FTE) to:</p> <ul style="list-style-type: none"> do research on the consequences of CBDC from the technological, economic, and policy point-of-view (before implementation); constantly monitor, evaluate, and have discussions with the economic agents, or even do necessary adjustments on the CBDC design or policies (after implementation)

CBDC Design Options	Impacted Economic Agents	Potential Efforts or Impacts
		Would have to comply to all kinds of regulations that are now imposed on commercial banks, such as know your customer (KYC) and anti-terrorism financing and money laundering.
		Would probably need to hire a specific technology consulting firm to build the technology framework.
		Would need to manage the potential competition between the commercial bank deposits and CBDC.
		Would need to do 'marketing' efforts to the financial institutions to ensure that they would not overreact to CBDC.
		Would need to provide more liquidity provision for commercial banks and determine what kinds of collaterals it would accept from the commercial banks.
	Commercial banks and other financial institutions	Would need to compete with CBDC (i.e., bank deposits versus CBDC), which require them to: <ul style="list-style-type: none"> • pay more interests to attract funding; and/or • decrease their dependencies on debt-financing and increase their equity-financing.
	Government	Would need to change or revise some laws or regulations.
		Would need to design fiscal policy rule due to the possibility of increasing seigniorage revenue and seigniorage outflows after the introduction of CBDC.
		Would have additional fiscal space due to more tax revenues and less spending to bail-out the banks.
	Households and non-financial institutions	Would have more convenient means of payment (could pay through the Internet or do cross-border payments in easier ways and with less administration fee/costs).
		Would have another safer option to store their money.
		Would have extra income due to the government's windfall gain from issuing CBDC (however, this is highly dependent on the fiscal policy of the government).
Wholesale CBDC	Central bank	Would need to consult the wholesale money market participants to predict/estimate the demand of the Wholesale CBDC and to gather inputs on: <ul style="list-style-type: none"> • the desired interest rates; and • the remunerations rate, so that the non-bank financial institutions and large multinational corporations are interested to hold the Wholesale CBDC.
		Would need to estimate the impacts of the Wholesale CBDC to the repo market; the Wholesale CBDC should

CBDC Design Options	Impacted Economic Agents	Potential Efforts or Impacts
		not interrupt repo market overnight to ensure the financial stability.
		Would need to periodically evaluate the conditions of the wholesale money market (after the introduction of the Wholesale CBDC) and provide regular reports to or conduct discussions with the wholesale money market participants.
	Commercial banks and other financial institutions	Would have another option to store their money.
	Government	Would lose the demands of its instruments that they issue, especially their short-term securities that are traded in repo market. However, the government would also gain more demands for the longer-term securities since this kind of securities can be used by central bank as the assets to back the CBDC.
FrDB CBDC	Central bank	Would need to develop new framework for monetary policy, including to define collateral policy for commercial banks during the transition or implementation period, as well as to monitor the implementation of such policies.
		Would need to communicate and cooperate with the Parliament through the Ministry of Finance (or other regulatory bodies such as AFM) about the proposed CBDC design option(s) and the needed change on all related regulations.
	Commercial banks	Would need to do re-papering works due to its separation process into two legal entities: the full-reserve depository bank and the risk-taking investment bank.
	Government	Would need to implement countercyclical fiscal policy.
	Households and non-financial institutions	Would have more convenient means of payment (could pay through the Internet or do cross-border payments in easier ways).
		Would have other safer option to store their money.

4.3 Factors of TCE Transactional Dimensions

This section answers the third sub-research question as follows.

Sub-RQ3: What are the factors associated with the transactional dimensions of TCE that impact each economic agent in each CBDC design option?

Based on the conceptual model described in Section 2.3 and the analyzed interview results, the factors of TCE transactional dimensions that impact each economic agent are explained in the following sub-sections.

4.3.1 For Central Bank

The answers of the majority of the interviewees show that the transaction costs of the central bank due to CBDC issuance are contributed mostly by the uncertainty aspect and not by the transaction frequency and asset specificity aspects due to several reasons. First, there are no countries that have implemented CBDC, therefore it is difficult to analyze, evaluate, and predict the consequences of CBDC issuance, especially in Retail CBDC. Thus, this might impose a relatively high degree of uncertainty. Second, in Retail CBDC and FrDB CBDC design options, the central bank is not necessarily required to handle all the consumers' accounts. The process of handling and managing the consumers' accounts can be outsourced to the commercial banks, therefore the central bank does not need to expand its technology capability to handle and manage customer data and retail transactions. This idea can be seen in Figure 11. Also, in Wholesale CBDC, the central bank can utilize existing wholesale payment infrastructures. Thus, this might decrease the needs to deploy specific technology and human resources (lower degree of asset specificity).

Table 13 exhibits the summary of factors of TCE transactional dimensions (uncertainty, transaction frequency, and asset specificity) that were extracted from the answers of the experts.

Table 13 Factors of TCE Transactional Dimensions for the Central Bank

TCE Transactional Dimension	Factors	Factors ID
Uncertainty	Consumer risks preference that would lead to the uncertainty of CBDC demands.	CB-U-1
	The possibility of cyber-attack that may disrupt the central bank's operational system.	CB-U-2
	Unquantifiable CBDC demands or adoption rate.	CB-U-3
	Uncertainty of the combination of CBDC demands and other factors that could lead to digital bank run.	CB-U-4
Transaction Frequency	Transaction frequency does not have much impact to the central bank.	-
Asset Specificity	FTE (full-time equivalent) of human resources to analyze, evaluate, and predict the consequences of CBDC issuance.	CB-A-1

4.3.2 For Commercial Banks

The majority answers of the experts show that the transaction costs of the commercial bank due to CBDC issuance are also contributed mostly by the uncertainty aspect. Table 14 exhibits the summary of contributing factors of TCE transactional dimensions that were extracted from the answers of the experts.

Table 14 Factors of TCE Transactional Dimensions for the Commercial Banks

TCE Transactional Dimension	Factors	Factors ID
Uncertainty	Retail CBDC might compete with bank deposits, so that the commercial banks might need to increase their interest rates to attract funding which in turn will increase their interest expenses.	CmB-U-1
	The possibility of digital bank run where people might withdraw their money from the commercial banks and deposit it to the central bank in the form of CBDC.	CmB-U-2
Transaction Frequency	Transaction frequency does not have much impact to the commercial banks.	-
Asset Specificity	FTE (full-time equivalent) of human resources to analyze, evaluate, and predict the consequences of CBDC issuance, as well as to comply with the new rules set by the government and central bank.	CmB-A-1

4.3.3 For Government

Table 15 exhibits the summary of contributing factors of TCE transactional dimensions (uncertainty, transaction frequency, and asset specificity) that were extracted from the interviewees' answers for the government.

Table 15 Factors of TCE Transactional Dimensions for the Government

TCE Transactional Dimension	Factors	Factors ID
Uncertainty	The possibility of increased international cross-border transactions. For example, if the Eurozone decides to issue and use CBDC denominated I euro, the cross-border transactions will be easier, so that in bad times, for instance, there will be large CBDC movements to the more stable countries like Germany or the Netherlands.	G-U-1
	The possibility to modify existing or create new regulations related to CBDC, depending on the design options.	G-U-2
Transaction Frequency	Transaction frequency does not have much impact to the government.	-
Asset Specificity	Additional capability to process real-time economic data. The digital nature of CBDC enables the authority to obtain real-time data, so that it is important for the authority to be able to process and interpret the data for evaluation and decision-making purposes.	G-A-1

4.3.4 For Households and Non-financial Institutions

Based on the answers of the experts, there are no practical factors related to uncertainty, transaction frequency, and asset specificity that affect the households and non-financial institutions directly. Most of the experts explained that for households and non-financial institutions, CBDC is another way of

storing their money that is safer than the commercial bank deposits (because it is backed by the central bank), or another means of payment that is more convenient than the physical cash.

4.4 Characterized Transaction Costs

Finally, this section answers the fourth sub-research question as follows.

Sub-RQ4: What are the transaction costs for each economic agent in each CBDC design option?

After all of the factors related to the TCE transactional dimensions are determined, the transaction costs can be characterized by combining all of information in Table 12, Table 13, Table 14, and Table 15. First of all, all of the factors of TCE transactional dimensions are mapped to the CBDC design options to provide clear understanding of the factors affecting the economic agents in each of CBDC design option. This mapping can be seen in Table 16.

Table 16 The Factors of TCE Transactional Dimensions for Each Impacted Economic Agent in Each CBDC Design Option

Economic Agents	Retail CBDC	Wholesale CBDC	Full-Reserve Depository Banks
Central bank	CB-U-4 CB-A-1	CB-U-3 CB-A-1	CB-U-1 CB-U-2 CB-A-1
Commercial banks and other financial institutions	CmB-U-1 CmB-U-2 CmB-A-1	CmB-A-1	CmB-A-1
Government	G-U-1 G-U-2 G-A-1	G-U-2 G-A-1	G-U-2 G-A-1
Households and non-financial institutions	-	-	-

As can be seen in Table 16, there are two interesting findings that can be inferred. First, transaction frequency does not have much impact to all economic agents. This is aligned with the initial expectation in Sub-section 2.3.2. Most of the experts said that transaction frequency would not play significant role for all economic agents, regardless of the CBDC design option.

Second, households and non-financial institutions do not need to make investments or efforts in relation with the uncertainty, transaction frequency, and asset specificity dimensions of TCE. Instead, as detailed in Table 12, households and non-financial institutions could reap several benefits of CBDC, including the additional option (much safer option) to save their money and additional income due to the government's windfall as the result of issuing CBDC.

Then, based on information in Table 12 and Table 16, the transaction costs borne by each economic agent in each CBDC design option can be characterized as shown in Table 17.

Table 17 Transaction Costs of CBDC for Each Economic Agents in Each CBDC Design Option

Economic Agents	Retail CBDC	Wholesale CBDC	Full-Reserve Depository Banks
Central bank	Research and information gathering		
	Design and implementation		
	Monitor and evaluation		
	Liquidity provision	Communication to wholesale market participants	Development of new monetary policy framework
Economic Agents	Retail CBDC	Wholesale CBDC	Full-Reserve Depository Banks
Commercial banks and other financial institutions	Research and information gathering		
	Monitor and evaluation		
	Alteration of products behavior	Alteration of products behavior	Contracting (repapering) due to the separation of function
	Increase on interest expenses		
	Restructuring of balance sheet (increasing equity ratio)		
Economic Agents	Retail CBDC	Wholesale CBDC	Full-Reserve Depository Banks
Government	Regulation enforcement		
	Monitor and evaluation		

From Table 17, we can derive several insights. First, it can be seen that for all CBDC design options, central bank and commercial banks (and other financial institutions) are the ones that bear most of the transaction costs. This is quite logical because the central bank needs to do most of the works during the decision-making phase, implementation or transition phase, and the post-implementation phase of CBDC issuance, while the commercial banks are the most impacted economic agents, especially by the Retail CBDC design option. However, one thing that should be noted is that this research was done qualitatively, therefore this finding needs to be quantified to confirm and ensure which economic agents bear most of the transaction costs.

Second, households and non-financial institutions do not need to bear transaction costs when CBDC is introduced. To some extent, this might be true. However, this might not be the case as this finding might not be generalizable, thus further experimentation and evaluation that focused on the negative impacts of CBDC on the households and non-financial institutions need to be done to confirm this finding.

5 Chapter 5 – Conclusions and Discussions

This chapter provides the conclusions of this research as well as the discussions on the interview results, scientific relevance of this research, and reflections of the area of improvement and the recommendations for future research.

5.1 Conclusions

TCE framework can be used to characterize transaction costs by operationalizing its three transactional dimensions, which are uncertainty, transaction frequency, and asset specificity. In this research, through the in-depth semi-structured interview sessions with several experts from different background and expertise, TCE framework was successfully used to identify and characterize transaction costs of several CBDC design options. To organize the process of applying TCE framework to the evaluation of the CBDC design options, a structured set of research question containing a main research question and four sub-research questions was made. In Chapter 4, all the sub-research questions have been answered; thus, in this section, the main research question will be answered.

The main research question of this research is: “*How can transaction cost economics (TCE) framework be applied to evaluate CBDC design options?*” In this research, TCE framework was coupled with the semi-structured interview methodology, therefore the answer to this main research question is established based on this methodology.

First, four sub-research questions were formulated and specifically designed to answer the main research question. In this step, the TCE transactional dimensions were specifically included in the third sub-research question (Sub-RQ3). Second, a literature review was done as the preliminary study before proceeding to the interview part to establish a robust understanding of the concept of money, digital currency, cryptocurrency, and especially, the CBDC and TCE framework. The literature review also helped the researcher to identify potential experts that would be invited. Third, a semi-structured interview protocol was designed to gain insights of the experts. The interview questions were specifically designed based on the formulated sub-research questions so that the interview sessions would be more organized and structured, as well as be focused on answering the sub-research questions. Fourth, the list of experts was made based on several criteria, and the experts were then invited through emails. Appointments were then made with the experts who accepted the invitation. Fifth, the interview sessions were conducted and recorded using a voice recorder. All experts agreed to be recorded as long as their names were excluded in the report. Two interview sessions were done through phone calls, one interview session was done through Skype video call, and seven interview sessions were done in face-to-face conversations. Sixth, the interview recordings were transcribed; one interview recording file was broken and unrecoverable, while the other nine were successfully transcribed. Seventh, the transcribed interviews were coded using the two-cycles coding methodology in Atlas.ti 8 software. Eighth, based on the coded transcriptions, the first three sub-research questions were answered (the CBDC design options and their respective characteristics were described and explained; the impacted economic agents and their efforts and impacts were listed; and the operationalizing factors of TCE transactional dimensions were listed and elaborated). Finally, the transaction costs for each impacted economic agent in each CBDC design option were characterized.

In conclusion, this research has shown several CBDC design options, the impacted economic agents, and the characterized transaction costs borne by each economic agent in each design option. There are three CBDC design options explained in this research, which are the Retail CBDC, Wholesale CBDC, and the Full-reserve Depository Banks (FrDB CBDC). Amongst the impacted economic agent, the

central bank and commercial banks are the ones that bear most of the transaction costs, while the households and non-financial institutions do not need to bear transaction costs when CBDC is introduced. This finding, however, should be reassessed and reevaluated because it might not be generalizable to all cases. In addition, the characterized transaction costs should be quantified to obtain a more accurate view of the total transaction costs of each CBDC design option. This research thus has provided a foundation for further research or studies related to the transaction costs of CBDC.

5.2 Discussions and Reflections

5.2.1 Reflections on the Interview Sessions

After conducting all the interview sessions with experts from various professional backgrounds, the researcher finds several interesting findings. First, not all the experts were sure and optimistic about central banks issuing CBDC. Some experts even said that they did not have any preferences related to the CBDC design options. However, to keep the conversation going, they explained one of the CBDC design options that they thought would be less disruptive to the whole financial stability.

Second, to some experts, CBDC is not the last or ultimate form of digital money. Indeed, CBDC is preferred by the regulators as the future of money. And if the central banks finally proceed to issue CBDC, it would be backed by the central bank and it would have a strong legal position compared to other privately issued digital currencies. However, some experts thought that CBDC is only a step towards the complete digital monetary reform in which all the bank balance sheets are abolished²⁶. The money would not be a claim on the central banks' or commercial banks' or any other entities' liability anymore; money will be a monetary object in a digital form like metal coins, a monetary object that can be owned by the users. As a consequence, central banks are not needed anymore. Instead, it would evolve to a central monetary authority that operates without balance sheet; it would use a register to track the ownership of the digital money. This idea is interesting because it offers another perspective of monetary reform that is not based on currently-discussed solutions such as narrow banking and full-reserve banking. However, this research does not focus on this idea specifically. This idea could be further analyzed or evaluated using TCE framework in future research.

Third, most of the experts said that the households are not impacted directly, especially in the Wholesale CBDC design option. As the results, there are no factors associated with the households that can be related to the TCE transactional dimensions. This may lead to an assumption or perception that the households do not need any costs to access CBDC. The researcher believes that this is not the case; the households, regardless of the CBDC design options, might need to bear some costs due to CBDC issuance. In future research, if exist, the aspects of households need to be more specified, probably like what explained in the work of Barrdear & Kumhof (2016).

5.2.2 Scientific Relevance

To the researcher's knowledge, this research is the first academic approach in implementing the TCE framework in evaluating the CBDC design options. CBDC itself is a relatively new topic with not-so-large literature base. Most of the literature is published by the central banks according to their own view on CBDC. Therefore, in an effort to obtain an unbiased view on CBDC, this research tried to involve

²⁶ For further readings on why the bank balance sheets should be abolished in this view, see McMillan (2014) and Wortmann (2018).

non-central bank entities: commercial bank, regulatory bodies, and relevant NGOs. However, due to time limitation, this research could not involve experts from the academic background.

Nevertheless, this research tried to put the very first stone to establish an understanding of transaction costs of CBDC through the lens of TCE framework. The transactional dimensions of TCE have been operationalized for all impacted economic agents. For example, what are the uncertainties that are relevant to central banks when they try to introduce CBDC? What are the specific assets that need to be deployed by the central banks when they try to introduce CBDC? And so on. Those questions have been answered not only by the central bankers themselves but also by other non-central bankers. The same thing is applied to other transactional dimensions. This is the first scientific contribution of this research.

Then, since this research involves the experts from the developed economies, their views on transaction costs of CBDC might not be able to be applied to the developing economies. For example, in the developed economies, the central banks may have possessed sufficient computing power to handle all the retail transactions in Retail CBDC design option, but in the developing economies, the central banks might need to deploy significant additional computing power to handle the retail transactions, thus increasing the asset specificity which in turn would increase the overall transaction costs. Therefore, the results of this research might only be generalizable to the developed economies. Future research could be conducted in developing economies and then a comparison might be made between the transaction costs of CBDC in the developed and developing economies. This is the second scientific contribution of this research.

5.2.3 Areas of Improvement

This research could be improved in several areas as shown in Table 18.

Table 18 Areas of Improvement of this Research

Areas	Areas of Improvements
Participants	Because of the time limit in this research, the researcher was not able to find as many experts as possible, especially from the academics group. There were three academics that were invited, but none of them accepted the invitation. Insights from the academics group could enrich the analysis and could provide other point-of-views that might not be provided by other groups of experts.
	Experts from groups other than the central banks (i.e., commercial banks, regulatory bodies, and NGOs) were mostly from the more developed economy in the Eurozone. Although some of those experts are also members of or involve in more international organizations (e.g., BIS and Positive Money), insights from experts with other economies within the Eurozone could provide richer yet (probably) convergent point of views related to the CBDC discussions.
	This research included two central banks, which were Bank of England and De Nederlandsche Bank, while initially the Sveriges Riksbank was also invited. However, there were no available experts at the Sveriges Riksbank during the data collection period due to the summer holiday. Insights from the Sveriges Riksbank could provide another point-of-view from a central bank outside of the Eurozone which has performed extensive research on CBDC and has a concrete plan to issue CBDC (in their case, e-krona).

Areas	Areas of Improvements
Research Methodology	Due to the time limit, this research used one-round semi-structured interview as the way of obtaining data and insights from the experts. To gain more reliable data, other than involving more experts, this research could also use a multi-rounds semi-structured interview methodology or a multi-rounds expert/panel discussions methodology, such as Delphi method or focus group discussion.

5.2.4 Recommendations for Future Research

This research has set the foundation to estimate transaction costs using qualitative methodology. Therefore, there are several recommendations for future research that can be based on this research. First, a research about the *analysis of the transaction costs of introducing CBDC in the Eurozone* by involving ECB and other European central banks. Or, it could be done outside of the Eurozone, probably in less developed economies, to contrast with the results achieved in this research.

Second, a research about the *analysis of the effect of international spillover of CBDC issuance*. Currently, it is most probably hard for a country to not participate in international economy activities. Therefore, if a country decides to introduce CBDC, it is important to evaluate the possible consequences of international spillover. For example, when the Eurozone finally decides to use CBDC, they might also want to consider its effects to other countries, especially from economic and political perspectives. This idea was also mentioned in one of the interview sessions.

Third, a research about the *establishment of quantitative research based on the characterized transaction costs in this research*. Due to the time limit, the identified transaction costs in this research have not been quantified. The quantification of the characterized transaction costs might confirm or reject the results achieved in this research. Most importantly, it could provide more valuable insights for other central banks or related authorities that that plan to explore or issue CBDC.

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Appendix

Appendix A – Interview Protocol

Evaluation of Central Bank-issued Digital Currency (CBDC) Implementation Designs using Transaction Cost Economics Perspective

Interview Protocol

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1. Introduction

This research evaluates several implementation designs of Central Bank-issued Digital Currency (CBDC) from transaction cost perspective. Aggregate transaction costs are evaluated by determining transaction costs that incurred by each economic agent. Transaction costs for each economic agent are estimated using different approaches. This research will be done qualitatively through semi-structured interviews.

2. About the Researcher

I am a second-year student in Master Management of Technology program in the Faculty of Technology, Policy, and Management (TPM), Delft University of Technology. My research supervisor is Prof. dr. Cees van Beers and I am working together with Martijn van der Linden, a PhD candidate in the TPM faculty.

3. Semi-structured Interview

3.1 Criteria for Participants

This research will gain insights of participants from different groups, i.e., central banks, commercial banks, independent regulator, academics, and NGOs. However, this research does not involve all central banks. In this research, Bank of England (UK) and Sveriges Riksbank (Sweden) are included because they have conducted more extensive studies compared to other central banks. Additionally, since the research is mainly based in The Netherlands, the De Nederlandsche Bank is also of interest in this research.

3.2 Questions used in the Interviews

Following table lists the questions that will be asked.

Coverage Area	Questions
CBDC	<ol style="list-style-type: none"> 1. Are you familiar with the phenomenon of central bank-issued digital currency (henceforth, CBDC)? Can you please describe or define CBDC based on your view? 2. According to you, what are the possible designs of CBDC implementation? <ol style="list-style-type: none"> a. In which monetary/banking system(s) those designs can be implemented (e.g., full reserve banking, fractional reserve banking, narrow banking, free banking, etc.)? b. From the perspective of money characteristics, in each design: <ul style="list-style-type: none"> – Should it be universally accessible (i.e., all economic agents can have access to central bank liabilities)? – Which function(s) of money that serve primarily (medium of exchange, store of value, or unit of account)? – Which economic agents (households and firms, government, commercial banks, central banks) that become the vantage point? c. From the perspective of monetary design: <ul style="list-style-type: none"> – Should it feature peer-to-peer or multitier payment? – Should it be anonymous? – Should it be interest-bearing? Should the interest be allowed to become negative? – Should central banks maintain or remove deposit guarantee scheme? d. From the perspective of its technology: <ul style="list-style-type: none"> – Should it use distributed ledger (or blockchain) technology? – Should it use centralized architecture? 3. Which design(s) do you prefer? Why do you prefer those particular design(s)?
Transaction Costs	<p>Determining Economic Agents</p> <ol style="list-style-type: none"> 1. In the CBDC design(s) that you prefer, which are the impacted economic agents? <ol style="list-style-type: none"> a. Are households impacted? b. Are non-financial corporations (public and private enterprises that produce goods or provide non-financial services) impacted? c. Is government impacted? d. Are commercial banks and other financial corporations (investment banks, pension funds, insurance corporations) impacted? e. Are central banks impacted? f. Are there any other impacted economic agents? <p>Estimating Types of Transaction Costs for Each Agent and the Factors that Influence Them</p> <ol style="list-style-type: none"> 1. For central banks:

Coverage Area	Questions
	<ol style="list-style-type: none"> a. What are the processes involved required in introducing or implementing CBDC economy? <ul style="list-style-type: none"> – What processes have been or are involved during decision making phase? – What processes may be involved in implementation phase? – What processes may be involved in post-implementation phase? b. What are the specific resources used in each process or phase? c. What are the specific efforts in each process or phase? d. During each process or phase and in each the preferred implementation design(s): <ul style="list-style-type: none"> – Which factors or risks cannot be quantified and/or controlled? – Which factors lead to uncertainty of the output of the process or phase? – Which factors related to the specificity of deployed resources in the process or phase (i.e., technology and human resources)? e. To what extent those factors influence each process or phase (e.g., dragging the decision-making process or requiring additional resources to be deployed)? f. In the preferred CBDC implementation design(s), will the frequency of transactions using CBDC incur significant efforts for central banks in maintaining macroeconomic stability through monetary policy (e.g., requires stricter monitoring or higher operating costs)? If yes, what are the efforts? <ol style="list-style-type: none"> 2. For commercial banks and other financial corporations: <ol style="list-style-type: none"> a. Related to financial products and services portfolio, in the preferred CBDC implementation design(s): <ul style="list-style-type: none"> – What are the financial products and services that may be affected? – Which aspects of financial products and services that may be affected? – Which factors or risks cannot be quantified and/or controlled that may lead to the uncertainty behaviors of financial products and services? – Do banks need to deploy specific resources to comply with the CBDC economy (e.g., new technologies, human resources, etc.)? – Will the frequency of transactions using CBDC incur significant efforts for commercial banks in providing financial products and services to their customers (e.g., requires redesign of banks' financial products and services portfolio or banking channels)? If yes, what are the efforts? b. Related to the activities of commercial banks in the economy, during the transition period and after the introduction of CBDC: <ul style="list-style-type: none"> – Do commercial banks need to adjust their functions or roles in the economy?

Coverage Area	Questions
	<ul style="list-style-type: none"> – To what extent CBDC affects interest expenses and non-interest expenses? – Which factors or risks cannot be quantified and/or controlled that may affect (decrease or increase) interest expenses and non-interest expenses? – Will the frequency of transactions using CBDC incur additional interest and non-interest expenses? If yes, what are the additional expenses? <p>c. Are there any other aspects of commercial banks and other financial institutions that may be affected by CBDC during transition period and after implementation?</p> <p>3. For government:</p> <ul style="list-style-type: none"> a. In the preferred implementation design(s), what are the impacts of CBDC economy to the fiscal policy (tax revenues and government spending)? b. In the preferred implementation design(s), to what extent the fiscal policy is affected? c. In the preferred implementation design(s), related to fiscal policy: <ul style="list-style-type: none"> – Which factors or risks cannot be quantified and/or controlled? – Do governments need to deploy specific resources to adapt with the CBDC economy (e.g., new technologies, human resources, etc.)? – Will the frequency of transactions using CBDC incur significant efforts for government in maintaining macroeconomic economy stability through fiscal policy? If yes, what are the efforts? <p>4. For households and non-financial corporations, in the preferred implementation design(s):</p> <ul style="list-style-type: none"> a. What are the impacts of CBDC economy to household income? b. To what extent households' income is affected? <ul style="list-style-type: none"> – Which factors lead to uncertainty of households' income? c. What are the impacts of CBDC economy to household consumption? <ul style="list-style-type: none"> – Which factors lead to uncertainty of households' income? – Do households and non-financial corporations need to deploy specific resources to reap benefits of or adapt to CBDC economy? d. To what extent households' consumption is affected? e. Which factors lead to uncertainty of households' consumption behaviors?

Appendix B – List of Codes

B–1 First Cycle Coding

B–1.1 Predetermined Codes

Code	Code Group	Description
accessibility: restricted	CBDC Attributes	Represent the accessibility of CBDC (universal vs restricted)
accessibility: universal	CBDC Attributes	
anonymous: no	CBDC Attributes	Represent the anonymity of transactions using CBDC
anonymous: yes	CBDC Attributes	
distributed ledger: no	CBDC Attributes	Represent the nature of technology that can be used for CBDC
distributed ledger: yes	CBDC Attributes	
interest-bearing: no	CBDC Attributes	Represent whether the CBDC will be interest-bearing
interest-bearing: yes	CBDC Attributes	
money function: means of payment	CBDC Attributes	Represent the money function that served primarily by CBDC
money function: medium of exchange	CBDC Attributes	
money function: store of value	CBDC Attributes	
money function: unit of account	CBDC Attributes	
peer-to-peer: no	CBDC Attributes	Represent the nature of transactions using CBDC
peer-to-peer: yes	CBDC Attributes	
remove dgs: no	CBDC Attributes	Represent whether the deposit guarantee scheme (DGS) should be removed when CBDC is introduced
remove dgs: yes	CBDC Attributes	
agent: central bank	Economic Agents	Represent the list of economic agents that may be impacted by CBDC
agent: commercial banks	Economic Agents	
agent: government	Economic Agents	
agent: households	Economic Agents	
agent: non-financial institutions	Economic Agents	
agent: other financial institutions	Economic Agents	

B–1.2 All Codes at the End of the First Cycle

Code	Number of Appearances
#design options: full-reserve depository banks	1
#design options: payment CBDC	2
#design options: retail CBDC	4
#design options: wholesale CBDC	1
*defining CBDC	11
*describing CBDC design options	6
100% backed with cb liabilities	1
accessibility: restricted	0
accessibility: universal	4
accessibility: universal limited to residents	1
account-based	3

Code	Number of Appearances
agent: central bank	6
agent: commercial banks	7
agent: government	6
agent: households	3
agent: non-financial institutions	3
agent: other financial institutions	6
anonymity: political issue	1
anonymous: no	4
anonymous: yes	1
banking system: fractional reserve banking	4
banking system: separate concept with CBDC	1
CBDC and banking system: not connected	1
CBDC as store of value for other financial institutions	1
CBDC quantity will be limited	1
cb-efforts: analyze implications	1
cb-efforts: comply with regulations	1
cb-efforts: consult with wholesale market participants (after implementation)	1
cb-efforts: consult with wholesale market participants (before implementation)	2
cb-efforts: define collateral policy	1
cb-efforts: develop framework for monetary policy	1
cb-efforts: do research on CBDC	1
cb-efforts: estimate CBDC demands	1
cb-efforts: estimate impacts on balance sheet	1
cb-efforts: estimate impacts on repo market	1
cb-efforts: hire technology consulting firm	1
cb-efforts: inform and cooperate with the Parliament or government	3
cb-efforts: manage competition between banks and CBDC	1
cb-efforts: monitor & evaluate	3
cb-efforts: monitor the implementation of monetary policy and collateral policy	1
cb-efforts: prevent banks & financial institutions to overreact	1
cb-efforts: provide information to wholesale market participants	1
cb-efforts: provide more liquidity provision	1
cb-efforts: provide reports	1
cb-resources: economy-monitoring resources	1
cb-resources: FTE	2
cb-resources: none	1
cb-risks: consumers' risk preference	1
cb-risks: cyber-attack	1
cb-risks: digital bank run	2
cb-risks: foresee impacts on other markets	1

Code	Number of Appearances
cb-risks: independently introduced by other central bank	1
cb-risks: low CBDC demands	1
cb-risks: unquantifiable CBDC demands	4
cb-trans freq: necessary to determine issued CBDC quantity	1
cb-trans freq: no impacts	2
change the equilibrium prices	1
cmb are thinking to shrink their balance sheet	1
cmb might need to adjust	1
cmb: pay more for funding	1
cmb-effects: compete with CBDC	3
cmb-effects: higher interest expense	2
cmb-effects: lose transfer fees	1
cmb-effects: relies on fee income	1
cmb-efforts: communicate changes to consumers	1
cmb-efforts: increase equity ratio	1
cmb-efforts: re-papering	1
cmb-product impact: deposits	5
cmb-resource: FTE	1
cmb-risks: bank run	1
cmb-risks: consumers' risk preference	2
cmb-risks: financial crisis	1
cmb-risks: increased interest expenses	1
cmb-risks: lending could be more expensive	1
cmb-trans freq: no impacts	3
commercial banks will not change role	1
considered as branches of cb	1
definition: CBDC already exists to some extent as CB reserves	2
definition: electronic form of paper money	1
definition: similar to government bonds	1
definition: the first step of digital sovereign monetary reform	1
definition: widening access	2
design options: account-based vs token-based	1
design preferences: none	2
distributed ledger: no	5
distributed ledger: yes	0
gvt-efforts: change laws	1
gvt-efforts: design fiscal policy rule	1
gvt-efforts: regulate the usage of CBDC	1
gvt-efforts: restrict CBDC holding to residents	1
gvt-extra revenues	1
gvt-impacts: additional fiscal space	1
gvt-impacts: competitor for T-bills	1
gvt-impacts: countercyclical fiscal policy	2

Code	Number of Appearances
gvt-impacts: increase financial inclusion	1
gvt-impacts: increase tax revenues	2
gvt-impacts: less spending for bailing out banks	3
gvt-impacts: more tax revenues	2
gvt-impacts: reduce illegal activities	1
gvt-resources: economy-processing capability	1
gvt-risks: increased international cross-border transactions	1
gvt-risks: time deposit instability	1
gvt-trans_freq: no impacts	1
hh-impacts: convenient means of payment	1
hh-impacts: indirect	1
hh-impacts: less impacts during crisis	1
hh-impacts: safer store of value	2
hh-windfall gains from government fiscal policy	1
imperfect substitutability between CBDC and bank deposits	1
interest-bearing: no	5
interest-bearing: yes	2
money function: means of payment	2
money function: medium of exchange	2
money function: store of value	5
money function: unit of account	0
no exchange rate	1
no limits on its quantity	1
no need for full-reserve banking	1
not a radical change	1
pawnbroker for all seasons arrangement	1
peer-to-peer: no	1
peer-to-peer: yes	3
political issue	1
possibility to be interest-bearing after introduction	1
quantity policy for CBDC	1
remove dgs gradually	2
remove dgs: no	2
remove dgs: yes	5
requires minimal adjustments	1
risk: digital run	1
shadow banking might rise again	1
technically feasible	1
wholesale CBDC	1
will not happen soon	1

B–2 All Codes at the End of the Second Cycle

Code	Number of Appearances
#design options: full-reserve depository banks	1
#design options: retail CBDC	4
#design options: wholesale CBDC	1
*CBDC Design Options	6
*defining CBDC	11
100% backed with cb liabilities	1
accessibility: restricted	0
accessibility: universal	4
accessibility: universal limited to residents	1
account-based	3
agent: central bank	7
agent: commercial banks	7
agent: government	6
agent: households	3
agent: non-financial institutions	3
agent: other financial institutions	6
anonymous: no	5
anonymous: yes	0
banking system: fractional reserve banking	5
banking system: separate concept with CBDC	2
CBDC quantity will be limited	1
cb-efforts: analyze implications	1
cb-efforts: comply with regulations imposed to commercial banks	1
cb-efforts: consult with wholesale market participants (after implementation)	1
cb-efforts: consult with wholesale market participants (before implementation)	2
cb-efforts: coordinate with wholesale money market participants	0
cb-efforts: define collateral policy	1
cb-efforts: develop framework for monetary policy	1
cb-efforts: do research on CBDC	1
cb-efforts: estimate CBDC demands	1
cb-efforts: estimate impacts on balance sheet	1
cb-efforts: estimate impacts on repo market	1
cb-efforts: foresee impacts on other markets	1
cb-efforts: hire technology consulting firm	1
cb-efforts: inform and cooperate with the Parliament or government	3
cb-efforts: manage competition between banks and CBDC	1
cb-efforts: monitor & evaluate	3
cb-efforts: monitor the implementation of monetary policy and collateral policy	1
cb-efforts: prevent banks & financial institutions to overreact	1

Code	Number of Appearances
cb-efforts: provide information to wholesale market participants	1
cb-efforts: provide more liquidity provision	1
cb-efforts: provide reports	1
cb-resources: economy-monitoring resources	1
cb-resources: FTE	2
cb-resources: none	1
cb-risks: consumers' risk preference	1
cb-risks: cyber-attack	1
cb-risks: digital bank run	2
cb-risks: independently introduced by other central bank	1
cb-risks: low CBDC demands	1
cb-risks: unquantifiable CBDC demands	4
cb-trans freq: necessary to determine issued CBDC quantity	1
cb-trans freq: no impacts	2
change the equilibrium prices	1
cmb are thinking to shrink their balance sheet	1
cmb might need to adjust	1
cmb: pay more for funding	1
cmb-effects: compete with CBDC	3
cmb-effects: higher interest expense	2
cmb-effects: lose transfer fees	1
cmb-effects: relies on fee income	1
cmb-efforts: communicate changes to consumers	1
cmb-efforts: increase equity ratio	1
cmb-efforts: re-papering	1
cmb-product impact: deposits	5
cmb-resources: FTE	1
cmb-risks: bank run	1
cmb-risks: consumers' risk preference	2
cmb-risks: financial crisis	1
cmb-risks: increased interest expenses	1
cmb-risks: lending could be more expensive	1
cmb-trans freq: no impacts	3
commercial banks will not change role	1
considered as branches of cb	1
definition: CBDC already exists to some extent as CB reserves	2
definition: electronic form of paper money	1
definition: similar to government bonds	1
definition: the first step of digital sovereign monetary reform	1
definition: widening access	2
design preferences: none	2
distributed ledger: no	5
distributed ledger: yes	0

Code	Number of Appearances
gvt-efforts: change laws	1
gvt-efforts: design fiscal policy rule	1
gvt-efforts: regulate the usage of CBDC	1
gvt-efforts: restrict CBDC holding to residents	1
gvt-extra revenues	1
gvt-impacts: additional fiscal space	1
gvt-impacts: competitor for T-bills	1
gvt-impacts: countercyclical fiscal policy	2
gvt-impacts: increase financial inclusion	1
gvt-impacts: increase tax revenues	2
gvt-impacts: less spending for bailing out banks	3
gvt-impacts: more tax revenues	2
gvt-impacts: reduce illegal activities	1
gvt-resources: economy-processing capability	1
gvt-risks: increased international cross-border transactions	1
gvt-risks: time deposit instability	1
gvt-trans_freq: no impacts	1
hh-impacts: convenient means of payment	1
hh-impacts: indirect	1
hh-impacts: less impacts during crisis	1
hh-impacts: safer store of value	2
hh-windfall gains from government fiscal policy	1
imperfect substitutability between CBDC and bank deposits	1
interest-bearing: no	5
interest-bearing: yes	3
money function: means of payment	3
money function: medium of exchange	2
money function: store of value	7
money function: unit of account	0
no exchange rate	1
no limits on its quantity	1
no need for full-reserve banking	1
not a radical change	1
pawnbroker for all seasons arrangement	1
peer-to-peer: no	2
peer-to-peer: yes	1
political issue	1
possibility to be interest-bearing after introduction	1
quantity policy for CBDC	1
remove dgs gradually	3
remove dgs: no	1
remove dgs: yes	5
requires minimal adjustments	1

Code	Number of Appearances
risk: digital run	1
shadow banking might rise again	1
technically feasible	1
wholesale CBDC	1
will not happen soon	1