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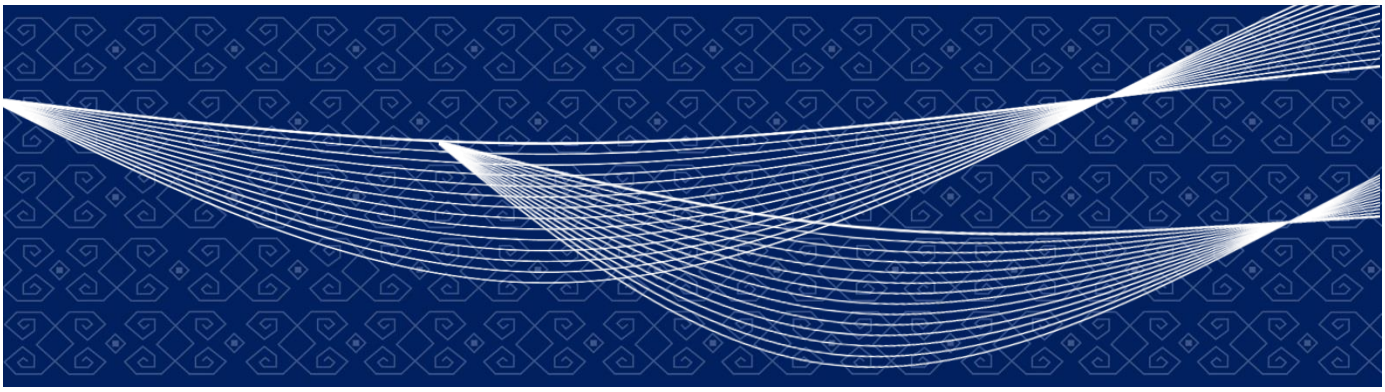

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WORKING PAPER

MONETARY POLICY STRATEGY IN THE PRESENCE OF CENTRAL BANK DIGITAL CURRENCY

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ABSTRACT

With their various motivations, many central banks still develop CBDC to explore its potentials and the drawback of implementation. This research examines the macroeconomic and monetary policy consequences, then determine optimal CBDC design to support monetary policy strategy. First, this research wants to develop DSGE model to quantify macroeconomic and monetary policy consequences in implementing CBDC. The DSGE model is consist of seven sectors namely households, retail firms, wholesale firms, capital producing firms, banks, central bank, and government. Shock generator that used in this model is technology shock and the shock on Taylor rule of interest rate. Second, as we know the outcome of the consequences, we continue to determine optimal CBDC design using SWOT with purposive sampling meta-analysis approach and its implementation strategies. According to the simulation, CBDC could effectively maintain inflation through CBDC rate. Meanwhile, optimal CBDC design that could support monetary policy is retail and wholesale coverage, interest bearing (wholesale) and non-interest bearing (retail) remuneration, account-based and token-based payment system, traceable degree of anonymity, hybrid architecture, DLT ledger system, and domestic and cross-border scope

Key words: CBDC, Optimal design, DSGE, SWOT, Monetary policy

JEL Classification: E42, E44, E52, E58, G21

1. Background

In this digitalization era, CBDC could be the key instrument to provide a safe and efficient means of payment. CBDC could enhance the cooperation of central banks, PSP, and other institutions to conduct digital payments (Morales-Resendiz et al., 2021). CBDC is a direct central bank liability in a form of digital currency (BIS, 2020). More than 60 central banks are interested in developing CBDC to see the potential and constraints in their implementation (Kalfon et al., 2021). The progress varies from the research stage to the launch stage (Boar & Wehrli, 2021). BIS, IMF, WEF, World Bank, and other stakeholders are involved in CBDC development and continue to support it until its reaches a larger ecosystem (Didenko & Buckley, 2021). The development of technology, new players such as fintech companies, declining cash usage, and private crypto-asset are also driving central banks to develop CBDC (CPMI, 2018a). Macroeconomic impact of CBDC implication also become the motivation to develop CBDC (Engert & Fung, 2017)

Digital cash, blockchain technology, smart contract, open banking, regtech, and etc. are some examples of fintech innovation (Kagan, 2020). According to Leong & Sung (2018), that fintech could create a new business value such as payments, advisory service, financing, and compliance. Those new business values could be very disruptive, and we might face digital banks that have a nimble footprint, innovative, transparent regulatory compliance, AI utilization, and using cryptocurrency hedging (Abrahams et al., 2016). Therefore, it is also possible that the central bank could create digital money that will have more convenience, security, costless, and resilience (CPMI, 2018a). Aside from central bank, the new players such as fintech companies also take part in the digital money development[1]. The fintech companies give us disruption by offering the customer easy access to digital payment that enables them to conduct transaction across many services such as transportation, accommodation, and entertainment in one access (OECD, 2020). That digitalization is also responsible for declining cash usage (McKinsey & Company, 2020). There is an example of this cash decline phenomenon, Sweden experienced a significant decline in cash usage, and most of the merchant is refusing cash as the means of payment (Riksbank, 2020). Aside from digitalization, the covid-19 pandemic also contributes declining in cash usage due to the urgency of social distancing (Auer et al., 2020a; Morales-Resendiz et al., 2021). Therefore, CBDC comes with an

1 Those new players are fintech companies such as start-ups to big tech that give disruption to the financial industry (Central Bank of Indonesia, 2019)

alternative means of payment that is issued directly from the central bank (ING Group, 2020)

Aside from declining cash usage, the development of private crypto-asset such as stablecoins and cryptocurrency makes CBDC gain attention from the central banks (Agur, 2018; Shin, 2020). It simultaneously increased the priority of CBDC development by the central bank across the world. The central bank doesn't want current their issued money to be replaced by private digital money. Yet, the central bank still not catching up with the technology. They need to be in the cutting-edge technology and it has some impacts on either regulatory framework or cyber security (Tan & Xue, 2021). The social cost from private crypto-asset become the concern of CBDC development (Agur, 2018). First, the high volatility of private crypto-asset such as Bitcoin makes it not viable as a stable means of payment (He et al., 2014). Second, the tragedy of Bitcoin exchange collapse such as Mt. Gox addresses the operational risk of private crypto-asset (Hu et al., 2020). Third, high power consumption due to its mining. For example, Malone & O'Dwyer (2014) found out that Bitcoin mining consumes around 5 gigawatts (the same amount as Ireland's electric consumption in early 2014). Fourth, private crypto-asset anonymity raises AML/CFT concerns (Agur, 2018). Fifth, the private crypto-asset has poor scalability if the number of transactions grows exponentially (A. Chauhan et al., 2018). Sixth, the central bank would likely lose its sovereignty if private crypto-asset become wider means of transactions[2] (Gross & Schiller, 2020). Among those concerns, sovereignty in CBDC is important because digitalization threatens the central bank over monetary policy and AML/CFT concern (Diez de los Rios & Y, 2020). AML/CFT is not merely an act of criminal but can disrupt the integrity and stability of the financial sector and the broader economy (IMF, 2021b).

There are also some compelling results of research towards its macroeconomic implication. Barrdear & Kumhof (2017) argue that CBDC could increase economic growth due to lower real interest rates, lower distortionary fiscal tax rates, and lower distortionary liquidity tax rates. Armelius et al. (2018) also argue that CBDC could increase national output due to the lower real interest rate. It makes the economic agents tend to increase consumption and investment, thus it would increase national output. However, Chiu et al. (2019) have a different perspective related to economic growth, they found out that

2 It can be seen from around 7500 private digital currency is emerged until now, which means the central bank did not have any surveillance on it (Gross & Schiller, 2020)

CBDC could raise commercial banks' competition, thus they would be raising their deposit rate, increasing intermediation, and increasing national output. Contrary to their result, there are also some results that CBDC could decrease national output. Keister & Sanches (2020) argue that CBDC could decrease credit supply, it would reduce bank lending power, thus decreasing national output. Gross & Schiller (2020) also have a similar perspective that CBDC could decrease commercial bank lending power and reduce the national output. Another perspective was founded by Jia (2020) through substitution effect, negative CBDC rate could drive people to save less and consume more, due to the reduced saving, the investment also reduced, thus it would reduce national output. Different perspective also founded by Bitter (2020), CBDC could drive people to convert their deposit and saving to CBDC because they consider CBDC as riskless asset, thus it would reduce bank lending power and reduce national output

Aside from the retail side, there is a narrowly provided CBDC only to particular institutions such as commercial banks and non-bank financial institutions namely wholesale CBDC (Bech & Garratt, 2017). The central bank wholesale CBDC focuses on the cross-border payment efficiency, development of capital markets, enhancement of cyber resilience, and improvements in securities trading and settlement (Boar & Wehrli, 2021). Wholesale CBDC could reduce the transaction cost and make the liquidity easier to get from the interbank market by using DLT[3] (CPMI, 2018a). Through this technology, the wholesale CBDC is also able to provide near a real-time settlement in the interbank payment, reduce reconciliation, reduce recording, and associated funds transfer on the trade date (CPMI, 2017). However, the DLT that will be used for CBDD is more likely different from cryptocurrency, it won't be permissionless so the central bank could maintain its sovereignty and be able to monitor money circulation (Beau, 2021). Experiments organized by Bank of Canada et al., (2018) demonstrated that the wholesale CBDC could improve stability, resilience, widen access, and reduce transaction cost. Also, Project Helvetia announced that DLT in wholesale CBDC was legally feasible and robust (BIS et al., 2020).

To distinguish CBDC from other kinds of money such as cryptocurrency, cash, etc., we could describe it into the taxonomy of money. Taxonomy of money is a Venn diagram that classifies money based on its characters from the past, present, and future (Bech &

3 The number of intermediaries will be reduced in DLT, so payment, clearing, and settlement will be more efficient (CPMI, 2018a)

Garratt, 2017). It also illustrated the four key properties such as issuer, accessibility, form, and technology. CBDC is divided into 2 main strands, which are retail CBDC and wholesale CBDC. Retail CBDC is focused on the general public, which is for all end users. On contrary, wholesale CBDC is focused on the financial institution that holds the reserve in their central bank.

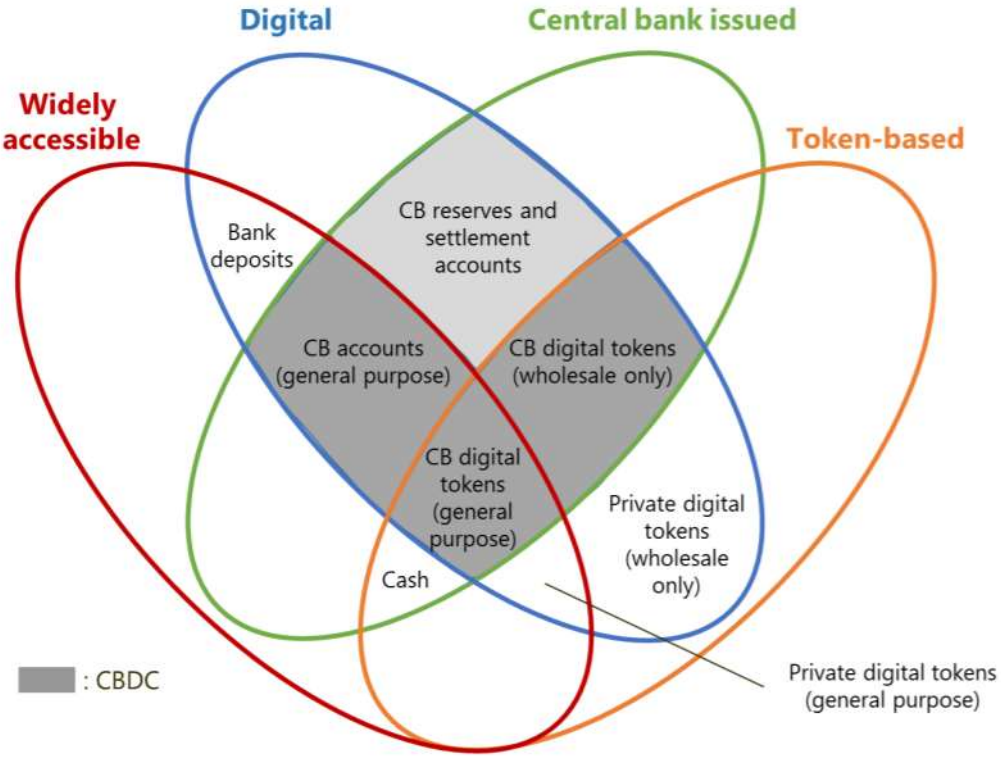

Figure 1.1 Taxonomy of Money

Source: Bech & Garratt (2017)

Many countries have continued their research on both retail and wholesale CBDC. For retail CBDC, the Bahamas has launched Sand Dollar since 2020. Bahamas motivation is improving financial inclusion, payment efficiency, and AML/CFT, it also allows CBDC to be used 24/7 in areas without internet with reduced transaction cost (Bharathan, 2020; Central Bank of the Bahamas, 2019). China also developing CBDC due to motivation of payment efficiency, financial inclusion, balancing private sector competition, AML/CFT and internationalization (Jiaying Jiang & Lucero, 2021; People's Bank of China, 2021). A pilot test has been conducted in Shenzhen, Suzhou, Chengdu, and Xiongan with a transaction value of 162 million USD, thus it encourages China to bring e-CNY to the Winter Olympics in 2022 to show the strength of their CBDC (Fanusie & Jin, 2021). Financial inclusion becomes their CBDC development motivations due to the declining

usage of cash[4] (Riksbank, 2020). In addition, the development of e-krona is also aimed at providing Sweden with a safe, convenient, and efficient means of payment (Armelius, Guibourg, et al., 2020). Meanwhile, Eastern Caribbean aiming financial inclusion and balancing the private sector competition (Eastern Caribbean Central Bank, n.d.-a). Some African countries such Jamaica is aiming for financial inclusion and payment efficiency, while Ghana is aiming for financial inclusion and AML/CFT, also Jamaica is also motivated by financial inclusion and payment efficiency (Gross, 2021)

Some countries are also still in development progress, for example, the United States with the Boston Fed and MIT is currently in the CBDC development research to assess the speed, security, privacy, and resilience of CBDC (Reynolds, 2020). From several retail-CBDC developments in each country, most of their main motivation is financial inclusion

For wholesale CBDC, Switzerland and France are collaborating to develop a CBDC under Project Jura, they are focused on the efficiency of cross-border payments (Swiss National Bank, 2021). Through Jasper-Ubin Project, Canada developed a CBDC focused on clearing, settlement, and cross-border payments efficiency (Bank of Canada & Monetary Authority of Singapore, 2019). Hong Kong and Thailand are also developing CBDC through the Inthanon-LionRock Project to optimize wholesale cross-border payments with a streamlined intermediation model, real-time transfers, and atomic Payment-versus-Payment settlements (Pou, 2020). Project Stella that developed between the Central Bank of Japan and the European Central Bank is exploring the innovative cross-border payment (Bank of Japan, 2020). It can be seen that most of the wholesale CBDC cases are more focused on improving interbank settlements and cross-border payment quality.

Some lessons can be learned through their obstacles in doing their development. In their pilot, Sweden's E-krona found out that technology and legal aspect regarding data privacy and e-krona value guarantor are not yet robust (Riksbank, 2021a). Sweden also realizes that they still need development the technology that allows CBDC to be conducted offline, implementing balance capping and interest rate feature, and robustness of payment system (Agur et al., 2018). Regarding the possibility of offline

4 Sweden to develop e-krona due to a decline in the use of paper money, moreover, the majority of payments are using digital money (Riksbank, 2020)

CBDC payment, the Uruguay pilot test found out that they can use USSD from their SIMCARD as an alternative of payment methods when it's offline (Bergara & Ponce, 2018). However, lessons learned also could be taken from countries that canceled their CBDC development. Denmark concluded that CBDC does not offer significant facilities that their existing payments infrastructure does not have (Margulies, 2021). Ecuador once launched a CBDC but they disbanded it because it was less efficient with private players (Arauz et al., 2021). The Central Bank of Poland also concluded that they could not identify any consumer or business demands that could be met if they developed a CBDC (Margulies, 2021). The Fed also has not yet decided to develop CBDC until they can assess financial stability asses and overcome cyber-attack risk (Shapoval, 2020). Most of them discontinued because the cost is greater than the benefits, so it has not yet become their priority.

From those use cases of CBDC development, it seems that there is no best design among CBDC development[5]. CEMLA (2019) also argues that there is no "one-sized-fits-all" CBDC design, it needs to be adjusted with the countries capability and needs. Even so, regardless of their choices of CBDC design, the central bank also must have a clear role between operator and supervisor, so it won't disrupt the environment with other financial entities (BIS, 2021b). CBDC design also must be interoperable so It can be integrated with other entities such as financial institutions (Kudrycki, 2021). Regarding the data concern, CBDC must ensure it is reliable and resilient, especially regarding the risk of user data (Morales-Resendiz et al., 2021). CBDC must be implemented to solve the problem of their country, not merely due to the trend of CBDC development, thus there is no need of hurry in CBDC implementation (Central Banking Newsdesk, 2021a; King, 2021). And lastly, CBDC can't harm the monetary policy and financial stability, coexist with cash and other means of payment, which flexible and innovative ecosystem of payment, and promote broader innovation and efficiency (BIS, 2020)

Research about macroeconomic impact of CBDC implementation is still limited to argumentation and economic model simulation. Some DSGE model simulation are

5 It can be seen from the development of each type of CBDC in various countries, retail CBDC is more likely in developing countries where financial inclusion is still concerning. Wholesale CBDC is more likely in developed countries that already have good financial inclusion. However, this cannot be considered in choosing a CBDC design because Sweden which is has a high level of cashless chooses the retail CBDC design. Economic conditions, consumer behaviour, banking system, and accessibility are the factors in determining the design. The high cost of developing CBDC requires the right decision (Kiff et al., 2020b)

conducted by Ferrari et al. (2020), Gross & Schiller (2020), and Barrdear & Kumhof (2017). Non-DSGE model also conducted by Davoodalhosseini et al., (2020), Agur, Ari, & Dell'Ariccia (2019), Kim & Kwon (2019) and Andolfatto (2018). Most of the research of macroeconomic impact of CBDC implementation still in the argumentation. For example, (Agur et al., 2018; Bindseil, 2020; BIS, 2021b; Bitter, 2020; Bordo & Levin, 2017; Carapella & Flemming, 2020; Nelson, 2021; Viñuela & Sapena, 2020; World Economic Forum, 2020). Therefore, it is important to enrich the macroeconomic impact of CBDC through the comprehensive analysis and learn from its consequences.

However, research related to the CBDC optimal design still a few and has limited design characteristics to explain. For example, Agur, Ari, & Dell'Ariccia (2019) found that CBDC should be between interest-bearing and non-interest bearing depending on its network effect. Zams et al. (2020) found that non-interest bearing is the most optimal CBDC design. Both of them only cover CBDC coverage and remuneration. Most of the research are only explain the possible characteristics of CBDC design. Such as research that explain the CBDC design from ledger system and anonymity perspective are conducted by Allen et al. (2020), Darbha & Arora (2020). The architecture of CBDC explained in Auer & Böhme (2020). Meanwhile, Kudrycki (2021) argue that CBDC must be properly design so it could unifies the distinction of CBDC. Therefore, it is important to conduct research about designing optimal CBDC with various design possibilities

Regarding of the gaps in the previous paragraph, it is explained the importance of discovering macroeconomic consequences of CBDC presence, as well as the monetary policy strategies. Therefore, this research wants to quantify macroeconomic consequences and monetary policy implication in the presence and absence of an interest and non-interest bearing CBDCs in competing with cash and bank deposits using DSGE model. Since there is no adequate research about optimal CBDC design, this research will determine optimal CBDC design to support monetary policy strategies using SWOT with purposive sampling meta-analysis approach.

We argue that implementing CBDC would likely improve monetary policy effectiveness due to effective response in expanding or contracting economy based on our simulation. It can be seen how CBDC rate effectively reduce inflation when economy starting to overheat and improve output when there is a technological advance. This result also aligned with Ammu George et al. (2021), Gross & Schiller (2021), Lim et al. (2021) in their DSGE simulation. So, we proceed to examines which optimal CBDC could

be designed. We therefore propose that CBDC would be optimal if retail and wholesale coverage, interest and non-interest bearing remuneration, account and token based payment system, traceable degree of anonymity, hybrid architecture, DLT ledger system, and both domestic and cross-border coverage. This result also complementary with Agur et al. (2021), Allen et al. (2020) and, Darbha & Arora (2020)

This research will be divided into five chapters. This chapters explain about this research foundational concept. Second chapter will rigorously discuss about CBDC from every aspect. Third chapter consist of the data and methods that will be used. Fourth chapter is conducting log-linearization. Fifth chapter will define the equilibrium. Sixth chapter will explain shock generator for the simulation. Seventh chapter will shows the simulation result from DSGE. Eight chapter will define optimal CBDC design as well as its strategies. Lastly, ninth chapter will be the conclusion of this research, followed with the policy implication and its recommendation.

2. Literature Review

2.1 CBDC Modelling

From a theoretical point of view, the introduction of central bank digital currency poses some challenging questions relating to the supply of public and private money and the ability of the central bank to utilize CBDC as a tool to increase the efficiency of monetary policy. Despite its potential, CBDCs could threaten the stability of banking and financial systems. Bank runs and disintermediation may occur when substantial amount of bank deposits are converted into CBDCs. Deposits outflow decrease banks funding ability and therefore, decline the volume of loan, investment, and economic activities in general (Gross & Schiller, 2021). Thus, the focus of theoretical literature in CBDC modelling lays in the effect of CBDC on commercial banks, monetary policy, Financial stability, and welfare implications. Literatures in this topic of research can be divided into three strands (Ferrari et al. (2020) [20]): papers introducing a CBDC in general, papers presenting a CBDC in DSGE model, and those analyzing a CBDC in an open economy setting.

2.1.1 Non-DSGE Model

In the first strand, i.e., non-DSGE modelling of CBDC, many researchers utilize stylized and often two-period model to assess the implication of CBDC in domestic economy. Agur et al. (2021) discuss the optimal design of interest and non-interest bearing CBDCs. In this network effect induced environment, economic agents may

choose cash, CBDC, and bank deposits based on their preferences over anonymity and security. Two-period model economy which consists of households, banks, firms, and a central bank is considered to maximize welfare. In the first period, the central bank decides whether and in what form to introduce a CBDC. Then in the second period, households decide to use cash, bank deposits, and CBDC (if introduced by central bank) in their transactions. Commercial banks extend loan to firms by using deposits from households. It is found that, when network effects matter, the interest bearing CBDC can be introduced by central bank to alleviate the trade-off between maintaining intermediation versus the diverse instruments of payment.

Andolfatto (2018) develops an overlapping generation model as a combination of the Diamond government debt model and Klein-Monti monopoly bank model to study the impact of interest bearing CBDC on monopolistic banking sector. It is shown that CBDC has no damaging effect toward lending activity of banks. More precisely, if CBDC interest rate is independently set of the interest of reserve, then the establishment of CBDC won't discourage the lending activities. Accordingly, if CBDC interest rate is fixed below the interest of reserve, then there is an incentive for the monopoly banks to match the CBDC rate for the purpose of retaining deposits. Thus, it is shown by the model that introduction of an interest-bearing CBDC does reduce bank monopoly profit but does not necessarily lead to bank disintermediation.

The optimal monetary in environment where cash and CBDC are co-exist is studied by Davoodalhossein (2018). By adapting Lagos-Wright model into two-period setting, i.e., decentralized and centralized markets, it can be analyzed an economy with only cash, only CBDC, or both of cash and CBDC. It is found that, under small carrying cost, the introduction of CBDC enables the central bank to acquire better allocations than with cash. By calibrating the model to the Canadian and US data, it is revealed that introducing CBDC can lead to an increase of up to 0.64 percent and 1.6 percent in consumption for Canada and for the US, respectively. The Lagos-Wright model with decentralized-centralized markets is also considered by Williamson (2021). Chiu, Davoodalhosseini, et al. (2019) and Chiu, Jiang, et al. (2019) develop a model of banking system with imperfect competition to investigate the effect of general equilibrium of establishing CBDC. It is discovered that the introduction of CBDC as an outside option for households, can still improve the efficiency of bank intermediation and increase lending and aggregate output even if its usage is low. Furthermore, when the model is calibrated to the US economy, it

is shown that CBDC can increase the volume of bank lending and investment by 6 percent under proper interest rate. The output can also be increased by a maximum of 1 percent.

Keister & Monnet (2018) study the effect of CBDC establishment on the financial stability under the condition of private information about quality of assets hold by the bank. In this work the seminal model of Diamond-Dybvig on bank runs is modified in such a way patient and impatient agents face two types of liquidity shocks. It is shown that, by observing the funds inflow into CBDC, the central bank can deduce the financial condition of bank more quickly and monitoring the flow of funds into this new asset. Diamond-Dybvig model on bank runs is also adapted by Fernández-Villaverde et al., (2020) to study the impact of CBDC on financial stability and bank runs in which banks can offer nominal contracts. Other papers thematically most similar with this are Bitter (2020), Kim & Kwon (2019) and Skeie (2020)

2.1.2 DSGE Model

It is well-known that the dynamic stochastic general equilibrium (DSGE) models are widely used to explain and predict co-movements of aggregate time series over the business cycle. DSGE models can be viewed as an objectively good representation of market economy mechanism. DSGE models can also be considered as the leading tool to evaluate the relative strength of interaction among agents (Christiano et al., 2018). Researches in the second strand employ DSGE framework to model the consequences of CBDC on economy. Compared to the use of the non-DSGE models, research on the effects of CBDC using the DSGE models is still rare.

Gross & Schiller (2021) build a DSGE model to evaluate the effects of interest and non-interest bearing CBDC, especially in the period of financial crises. Gertler-Karadi model are adopted by focusing the household utility maximization, bank intermediation in lending, and the central bank role. In particular, households have three instruments of saving with remuneration, liquidity, and risk exposures, i.e., bank deposits, CBDC, and government bonds. It is found that the effects of bank deposits crowd out can be mitigated by assigning additional central bank funds or setting a low CBDC interest rates to disincentivize large-scale CBDC accumulation. Barrdear & Kumhof (2017) propose a monetary-financial DSGE model and assess the steady state effect of an interest-bearing CBDC. Calibration of the model to pre-2008 US data shows that even if CBDC introduction of 30 percent of GDP would cause a bank deposits outflow, the output could still increase by 3 percent in the long run.

A New Keynesian DSGE model consisting of three economic sectors, namely households, commercial bank and central bank, is examined by Luo et al. (2021) to analyze the impact of electronic money (including CBDC) on monetary policy and, especially the impact of behavior changes on savings, loans, output, and interest rate. The simulation results suggest that electronic money exhibits asymmetric effect on savings and loans, but an irrational distortion on households, electronic money influences the interest rate in reverse manner leading to the management difficulties of the micro subjects and affecting the monetary policy effectiviness, and electronic money has the effect of restraining risk. Lim et al. (2021) develop a DSGE model equipped with cash and digital currency to quantify the effect of loan prime rate (LPR) setting and CBDC introduction in China. Using Bayesian estimations, the optimal LPR can be designed to improve the stability property of post-CBDC economy.

2.1.3 Open Economy Model

Open economy means an economy open to trade and capital flows. The third strand of research topic extend the DSGE models into open economy context. This direction is more challenging compared to a standard closed economy as we now allow, for instance, the world demand and transmission channel through exchange rate. The results regarding CBDC effect through DSGE modelling in open economy are thin. Calle & Eidan (2020) extend Barrdear-Kumhof model to a small open economy by introducing foreign sector, where export-import activities and capital flows are possible. It is discovered that the introduction of CBDC with an adjustable interest rate may improve the welfare and increase the monetary policy effectiveness. Moreover, exchange rate and inflation exhibit more stable movements. Ferrari et al. (2020) build a two-country open economy DSGE model to assess the international transmission of standard monetary policy and technology shocks in light of two scenarios, namely with and without CBDC, and to explore the monetary policy optimality and household welfare in the economies. It is shown that the introduction of CBDC strengthen the international spill overs of shocks to a significant extent, thus reinforce international connections. A DSGE model proposed by Benigno et al. (2019) discusses the two-country open economy nature of more globally issued crypto-currencies, which are different in safety and reputation with CBDC. The presence of a crypto-currency in a home and a foreign environment with two national currencies is analyzed in the framework of monetary policy autonomy.

2.2 CBDC and Macroeconomic Implication

A digital form of currency has been a central discussion among policymakers and economists. Voluminous frontier research and practical experimentation concerning CBDC have been conducted in the past recent years. Generally speaking, the literature can be categorized into two main strands. The first strand focuses on developing a formal model examining several aspects and consequences of retail CBDC. In contrast, the second strand mainly conducts practical experiments and narrative studies to evaluate the practical eligibility of wholesale CBDC implementation and its potential implications.

Several literature works have provided intense debates on the impact of retail CBDC on financial intermediation and stability. Kim & Kwon (2019a) argued that the issuance of an interest-bearing retail CBDC would essentially decrease the credit supply and raises the nominal interest rate, and lower a commercial bank's reserve-deposit ratio. It then leads to higher transformation maturity risks to commercial banks and financial instability. Keister & Sanches (2020) also demonstrated that an interest-bearing retail CBDC would crowd out bank deposits, raise the real interest rate on deposits, and exacerbate investment. On the contrary, Chiu et al. (2019) and Andolfatto (2018) also illustrated that in a non-competitive deposit market, retail CBDC acts as an outside option to depositors, capable of reducing commercial banks' incentive to restrain deposit supply. As a result, commercial banks supply more deposits, lower the loan rate, and expand lending.

Some authors also argued that the issuance of retail CBDC would deliver optimistic consequences on monetary policy. Dyson & Hodgson (2016) highlighted that when an interest-bearing retail CBDC entirely replaces the use of physical money, it allows the interest rate to be lowered below zero-lower-bound, widening the range of monetary policy. Bordo & Levin (2017) argue that retail CBDC also enables central banks to reduce their inflation targets. The rationale is that if CBDC is interest-bearing, the agents would only diversify their wealth into interest-bearing instruments controlled by the central bank. Mancini-Griffoli et al. (2018) also argued that the interest rate channel may be the most affected and could be strengthened by the presence of an interest-bearing retail CBDC. Changes in policy interest rates induce households and firms to rebalance investment and consumption between the future and the present, especially if these are exposed to interest-sensitive borrowing and saving instruments. Barrdear & Kumhof (2017) demonstrated that the issuance of retail CBDC leads to reductions in real interest

rates, distortionary tax rates, and monetary transaction costs. This consequently increases the steady-state level of the economy.

Some of them also proposed several monetary policy plans in the presence of retail CBDC. Barrdear & Kumhof (2017) argued that the retail CBDC rate should act as a business cycle stabilizer through which the central bank conducts either the quantity-based or the price-based CBDC policy in a countercyclical manner. Keister & Sanches (2019) derived the parallel-policy-CBDC optimal interest rate and shows that it balances two competing effects: a higher interest rate promotes more efficient exchange levels but decreases the level of investment. Chiu et al. (2019) demonstrated that if the rate of interest-bearing CBDC is set moderately, it could expand intermediation. However, when the CBDC rate is set too high, it causes disintermediation. Bindseil (2020) proposed a "tiered" interest rate on retail CBDC. He argued that excessive reductions in the interest rate could be politically difficult to accept in bad times. Therefore, it is proposed to solve the political acceptance of temporary very low-interest rates on CBDC by differentiating remuneration according to the volume of deposits held.

This strand of literature also addressed the optimum design of retail CBDC by considering several aspects. Agur et al. (2019) merely provided a theoretical analysis examining optimum retail CBDC designs between cash-like and interest-bearing CBDCs by mentioning the role of network effects. They argued that if the introduction of a CBDC threatens cash with extinction, an interest-bearing CBDC, with a negative interest rate, can compensate. Masciandaro (2018), Gnan & Masciandaro, (2018), and Borgonovo et al. (2018) also investigated the best retail CBDC design from the political economy approach. The results suggest that the individuals tend to value illiquidity risk and return, while anonymity seemed to play a minor role. As such, an account-based CBDC with interest-bearing possibly delivers the optimum form of CBDC.

Contrary to the first strand of literature, discussion on wholesale CBDC is mainly shaped through practical experimentation evaluating its eligibility, and narrative studies slightly addressed its consequences on financial stability and monetary policy. Bank of Canada et al. (2018) demonstrated that the wholesale CBDC is possible to implement. Bank for International Settlements et al., (2020) announced their "near-live" successful experiment on wholesale CBDC using distributed ledger technology (DLT) and token-based, implying its eligibility. Moreover, some believed that wholesale CBDC might deliver some potential advantages. Shirai (2019) emphasized that the wholesale CBDC may

enhance financial stability if the central bank extends the eligible financial institutions with access to reserve deposits at the central bank, such as insurance firms, pension funds, and other non-bank financial institutions. By this, the central bank could monitor and extend its policy transmission directly to these financial institutions. Šiaudinis (2019) argued that such an extension, particularly as an option for temporary *ad hoc* policy, can promote the future framework of monetary policy by complementing the bank-based transmissions. Some normative claims also delivered by (BIS, 2019) that wholesale CBDC implications are essential. Bank for International Settlements et al. (2020), in the Helvetia Project Report, argued that wholesale CBDC contributes to financial stability, in general, by avoiding credit and liquidity risks on the settlement asset, and would also necessarily impact monetary base composition. As each composition has different utility, it probably affects several financial aspects, such as the strength of money creation by the commercial banks and financial stability.

On the other hand, others claimed that wholesale CBDC brings no significant consequences on monetary policy and financial stability. Bindseil (2020) pointed out, with no formal arguments, that wholesale CBDC would not change the size of the monetary base so that it has no significant practical differences from the conventional system. World Economic Forum (2020) also claimed that wholesale CBDC, especially domestic coverage, may deliver no benefits if the current interbank payment is already efficient and sufficiently innovative.

2.3 CBDC Characteristics

CBDC design has its unique benefits and drawbacks aside from its inherent aspect. To investigate that, CBDC will be divided into many classifications such as coverage, remuneration, etc. Then, each classification will consist of its characteristic that would likely to contrary each other such as retail vs wholesale, interest-bearing vs non-interest bearing, etc. Each characteristic will be described in its overview, benefits, and drawback. Below is each CBDC characteristic but not limited to:

2.3.1 Coverage (Retail vs Wholesale)

Retail CBDC or also known as general-purpose CBDC is intended for widely available to all end-user as their means of payment (Cheng et al., 2021). It would be providing safe and reliable public payment methods. There is a lot of consideration that driving the development of retail CBDC. First, our world experienced a declining usage of

cash (Auer et al., 2020a; Wolf, 2021). Decreasing cash usage could lead to lower cash acceptance in merchants, like in Sweden. (Riksbank, 2020). Providing CBDC could overcome the decreasing cash acceptance by giving alternative means of payment. Moreover, the maintenance cost, logistics, and distribution of cash are quite high, thus cash becomes not efficient (Raghuveera & Bray, 2020). Second, CBDC is directly issued by the central bank, while retail CBDC is distributed for the people, thus it would promote financial inclusion by converting an unbanked person into a banked (Kiff et al., 2020b). Third, CBDC could be easily monitored due to its traceability, the database will be updated by changing the position of the account in every transaction (PwC, 2020). Its traceability also allows the central bank to know the exact quantity of issued CBDC (Sridhar & Horan, 2021). By knowing this, AML/CFT concerns would be supported (Agur, 2018). The extracted real-time data of economic activity also allow the central bank to perform smarter decision in policymaking (CPMI, 2018a). Moreover, central bank could directly transmit monetary policy through CBDC wallet. However, CBDC could not be anonymous to become traceable. It can't be avoided for people to have their privacy being sacrificed.

Contrary to retail CBDC, wholesale CBDC is intended for the interbank transaction such as interbank settlement and other wholesale transactions not for financial inclusion, it also serves the same purpose as central bank reserve (BIS, 2021b). Wholesale CBDC has similarities with RTGS, but it is enhanced by DLT in their ledger system (BIS et al., 2020). DLT enables us to gain a near-instant settlement, reduced intermediaries, reduced reconciliation, and synchronization within the distributed participant[6]. Usually, RTGS system is using telecommunication network that able to transmit and process the information in real-time (BIS, 1997). The participant is allowed to manage their transfer such as submission, validation, and recording (CPMI, 2018a). Wholesale CBDC is also allowed to be tokenized, thus will become their asset and those assets will be the sending value to the receiver without using intermediaries (Geroni, 2021). The central bank also could monitor real-time data and transmit policy directly to these financial institutions (CPMI, 2018a). Some research found that wholesale CBDC can provide several potential advantages. Shirai (2019) and the Committee on Payments and Market Infrastructures (2018b) emphasize that wholesale CBDC can improve financial stability by providing access for non-bank financial institutions (such as insurance and pension fund) to central

6 ibid

bank reserve. Wholesale CBDC also creates a better cross-border payment that has less cost, real-time settlement, and huge coverage (BIS et al., 2021). Šiaudinis (2019) argues that wholesale CBDC temporary ad hoc policies could promote a future monetary policy framework by complementing bank-based transmissions. Several normative claims from the Committee on Payments and Market Infrastructures (2019) and the Bank for International Settlements et al. (2020) in the Helvetia Project Report said that wholesale CBDC will give a contribution to financial stability by avoiding credit and liquidity risk in settlement assets, this will also have an impact on the composition of the monetary base. Since each composition has different uses, it may affect some financial aspects such as the money-creating power of commercial banks and financial stability. However, legal aspects also still being a concern of wholesale CBDC implementation. For example, Project Helvetia face a legal problem of central bank competence of issuing wholesale CBDC and status of central bank as legal tender (BIS et al., 2020).

2.3.2 Remuneration (Interest Bearing vs Non-interest Bearing)

Interest-bearing CBDC is a form of central bank obligation to pay interest on either token-based or account-based CBDC (CPMI, 2018a). CBDC allows the central bank to comprehensively monitor the amount of money circulating in the economy through the CBDC rate (Copik & Franke, 2020). The CBDC rate also could be adjusted depending on the policy directly into their CBDC wallet, which also make remunerated CBDC become versatile instrument of flexible transfer scheme (CPMI, 2018a; Davoodalhosseini et al., 2020; Nelson, 2021). Research by Beniak (2019) found that interest-bearing CBDC will make monetary policy more effective because it will make it the central bank easier to impact interest rates with CBDC rates. Also, positive interest rate payment would likely attract people to use CBDC, thus it could broaden the CBDC access (CPMI, 2018a). If CBDC fully replaced the cash, interest-bearing CBDC could be able to penetrate zero lower bound with negative rates to stimulate public consumption in the time of economic downturn (Davoodalhosseini et al., 2020). This feature would likely make CBDC similar to deposits or other assets, but, if CBDC is more beneficial, it could trigger crowd-out deposits, thus will make bank disintermediation (Agur et al., 2021; Chiu, Davoodalhosseini, et al., 2019; Kim & Kwon, 2019). The risk of bank disintermediation happened when people prefer CBDC rather than commercial bank deposits (Bian et al., 2021). In the worst case, it can create a concentration of deposits that can lead us to the bank run due to disrupted maturity transformation. (Fernández-Villaverde et al., 2020). However, negative rate could being a disincentive to CBDC holder, thus could prevent

bank disintermediation (Bindseil & Panetta, 2020). Interest-bearing CBDC also heavily relies on the internet and power. Interest payment or deduction of CBDC can be conducted if the devices are connected to the network, thus it will be unreliable when an outage happened (Shah et al., 2020). There is also additional cost in interest-bearing remuneration, such as administrative, management, and holding cost (Pfister, 2020). Also, interest payment is easier to be conducted in the centralized ledger and traceable account-based non-anonymous CBDC (BIS, 2020; CPMI, 2018a).

Contrary to interest-bearing, non-interest bearing CBDC is just like cash as usual and it is not interest-bearing. Same as cash, it will be used for daily payments by using denomination of national currency and can be exchanged in par in a commercial bank (Armelius et al., 2021). Due to its similarity with cash, non-interest bearing CBDC would reduce the demand of cash when the network effect at the point of cash disappearance (Agur et al., 2021). Armelius et al. (2018) argue that conversion from cash to CBDC depends on the deviation of CBDC benefit and cost of holding. Non-interest bearing also means that it could not be utilized as tools of monetary policy (Meaning et al., 2021). However, non-interest bearing CBDC could be a monetary policy tools such as transmitting helicopter money that is programmed according to monetary policy (BIS, 2020). Armelius et al. (2018) argue that when an economic downturn occurred, people tend to move their assets to CBDC due to consideration as risk-free even though without interest rate incentive, thus leading to bank disintermediation. From its reliability, non-interest bearing CBDC has the possibility of conducting offline transactions such as NFC or USSD[7].

2.3.3 Payment System (Account-Based vs Token-Based)

Account-Based CBDC relies on the authentication of the identity (Auer & Böhme, 2020b). It can be assumed that the asset claim is restricted to identity information like current bank transactions, thus it would be good in supporting AML/CFT concerns (PwC, 2020). Due to its restriction, account-based CBDC is only possible to be conducted in good internet and devices, which it can't be conducted offline (Didenko & Buckley, 2021). To conduct the transaction, the user needs to show their authority by proving their identity as the account through information such as password, PIN, fingerprint, etc. (Allen et al., 2020; Bank of England, 2020). Account-based CBDC also has an efficient scheme

7 Non-interest bearing CBDC enable conduct offline transaction if it has token-based payment system (Armelius et al., 2021)

of identity for its user, thus it could protect the users from cyberattack such as data abuse and hoarding while raising concerns about AML/CFT (BIS, 2021a). Bordo & Levin (2017) argue that account-based CBDC transactions could be quick and secure because verification is only using an identity that has been created from CBDC creation, thus it is cheaper and faster than token-based CBDC. Capacity of CBDC wallet also easily to implement in account-based payment system (CPMI, 2018a)

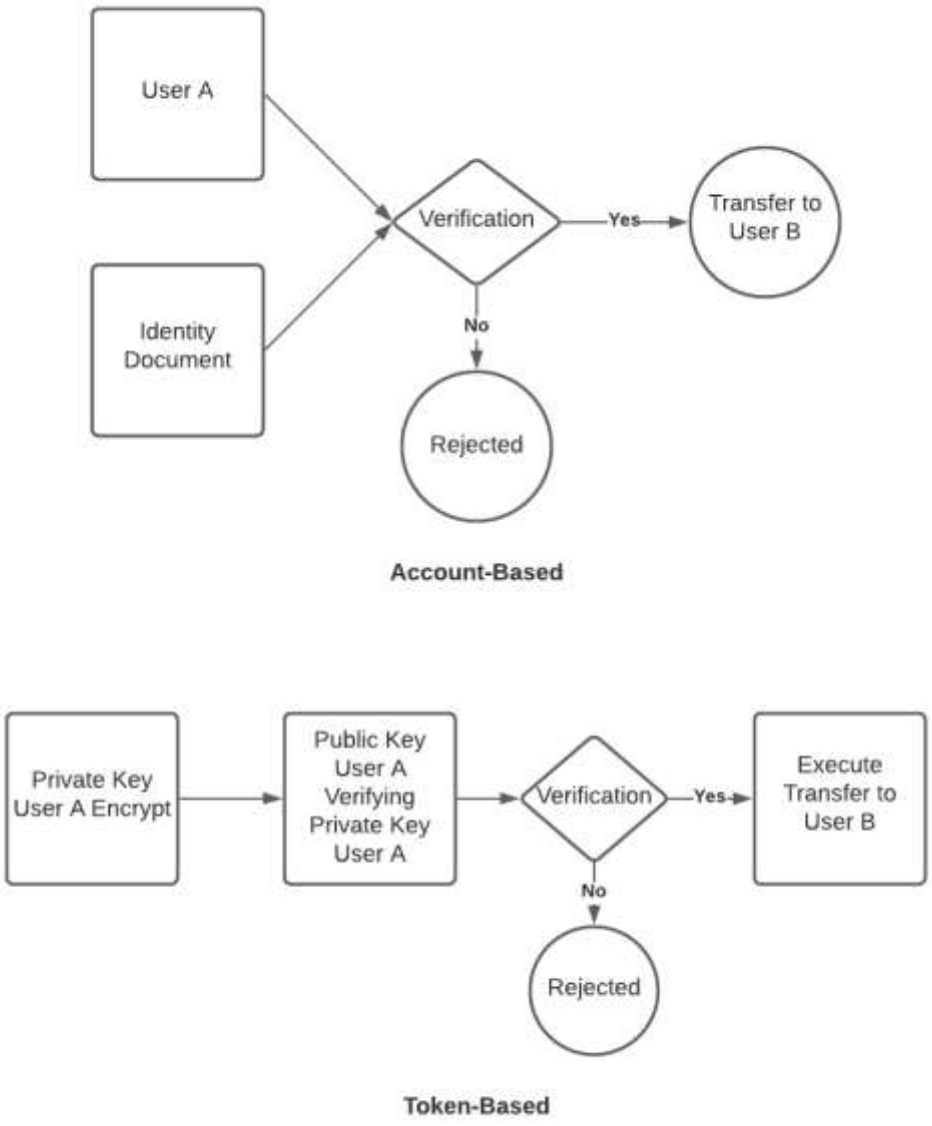

Figure 2.1 Comparison between payment systems

Source : Adapted from Auer & Böhme (2020)

On contrary, token-based CBDC relies on verification from the receiver to ensure the validity of the payment object[8] (CPMI, 2018a). The payment scheme of token-based CBDC is just like the cash transaction, also it was a store of value (Armelius et al., 2021). Token-Based CBDC will make sure of universal access as long as they obtained digital signature to conduct a transaction, and could be transferred directly to other users (peer-to-peer) without any third party (Auer & Böhme, 2020b). The anonymity on token-based CBDC can be adjusted to a certain degree, so it only extracts specific transaction information, thus still could raise AML/CFT concern (CPMI, 2018a). Offline payment also can be conducted in token-based CBDC by using technology such as NFC, USSD, or value-stored card, which means it's still being reliable when an outage happened (BIS, 2020; Kahn et al., 2018). One of the offline transaction consequences is the delay in reconciliation, which is it needs to wait for the device back to online so it would be synchronized with the system (Jiaying Jiang & Lucero, 2021). But there are some disadvantages for the user security, the owners need to keep their private key carefully, otherwise, the amount of money that they were held is lost (Auer & Böhme, 2020b). Also, Bordo & Levin (2017) argue that token-based CBDC is costly because every created token must be stored in the encrypted ledger, thus it's more expensive than account-based CBDC.

2.3.4 Anonymity (Anonymous vs Traceable)

CBDC could be designed in anonymous or full disclosure depending on the proposed design (Darbha & Arora, 2020). The anonymity could be ranged from completely anonymous to none (CPMI, 2018a). Offline transaction could be conducted in anonymous CBDC, as proposed in cash-like CBDC (Armelius et al., 2021). Anonymous CBDC means a user that conducted a transaction can't be identified and can't be traced, thus it can't be applied on the account-based CBDC[9] (CPMI, 2018a; Engert & Fung, 2017). User privacy is the main concern and is emphasized in this design (Bank, 2019). However, anonymous CBDC raises the issue of AML/CFT because the user can't be identified, such as Bitcoin (Agur, 2018). Most central bank is against the anonymous design of CBDC due to the possibilities of illicit activities (Kaminska, 2021). Also, the operational cost for anonymity is high because the information must be encapsulated,

8 Token-based also can be called value-based (CEMLA, 2019)

9 Account-based CBDC rely on verification of account holder identity, which impossible to be anonymous (CPMI, 2018a)

thus adding complexity to it. Due to its complexity, it has lack of scalability and has risk of hidden vulnerabilities. (Darbha & Arora, 2020).

On contrary, traceable CBDC offers the disclosure of identified information (Darbha & Arora, 2020). Traceable CBDC allows the central bank to gather digital records and traces, thus able to support AML/CFT concerns (CPMI, 2018a; Ma, 2021). With a lower privacy level, CBDC would be easier to be designed because there is less information that needs to be secured, which is more cost-efficient (Darbha & Arora, 2020). Sweden would make their CBDC traceable to protect users' rights and record the transaction (Riksbank, 2021b). Even though China also want to give their people privacy, China still applies managed anonymity, in which small transaction will be anonymous, but the large transaction will be traceable (People's Bank of China, 2021).

2.3.5 Architecture (Indirect vs Direct vs Hybrid)

BIS proposes possible three architectures of CBDC issuance, which are direct, indirect, and hybrid[10] [11]. Indirect CBDC means that the intermediary has a mandate to fully back each outstanding indirect CBDC-like liability to people to the retail consumer through its actual holding of CBDC that deposited at the central bank[12] (Auer & Böhme, 2020b). The central bank has no mandates of KYC, dispute resolution, and related services, also the central bank has no records of individual claims[13]. People will claim their CBDC in the intermediaries such as a commercial bank or other financial institution (PwC, 2021). The central bank is only responsible for each trust account's settlement, regulation, and CBDC issuance (Adrian, 2019). China plans to use two-tiered CBDC in their implementation, PBOC will issue and redeem CBDC to intermediaries, then the intermediaries will distribute the CBDC to people[14] (Jiaying Jiang & Lucero, 2021). However, when financial stress occurs, authority needs to prepare deposit insurance as it is not a direct claim of central bank (Auer & Böhme, 2020a)

10 All of those three architecture are compatible for both account and token based CBDC (Auer & Böhme, 2020b)

11 This architecture also known as one-tier CBDC

12 This architecture also known as two-tier CBDC (Ali, 2018)

13 ibid

14 Intermediaries that would likely to be used by China is commercial banks, payment platform (such as Alipay and WeChat Pay), and telecom companies (Jiaying Jiang & Lucero, 2021)

Direct CBDC means that the central bank is the only authority that handles payment service, which implies central bank has full knowledge of retail transaction[15] (Auer & Böhme, 2020b, 2020a). All of the people involved in CBDC transactions must hold an account in the central bank (PwC, 2021). However, the central bank scale of building and technical capabilities is most likely better be undertaken by the private sector, also the central bank needs to build related technologies that require a large-scale operational expansion which makes the central bank do beyond their mandates (Auer & Böhme, 2020b). Moreover, it also could be undesirable from the view of public trust (Allen et al., 2020). For the use case, the Bahamas uses direct CBDC by managing currency issuance, holding monitoring, and KYC/ identity infrastructure (Central Bank of the Bahamas, n.d.)

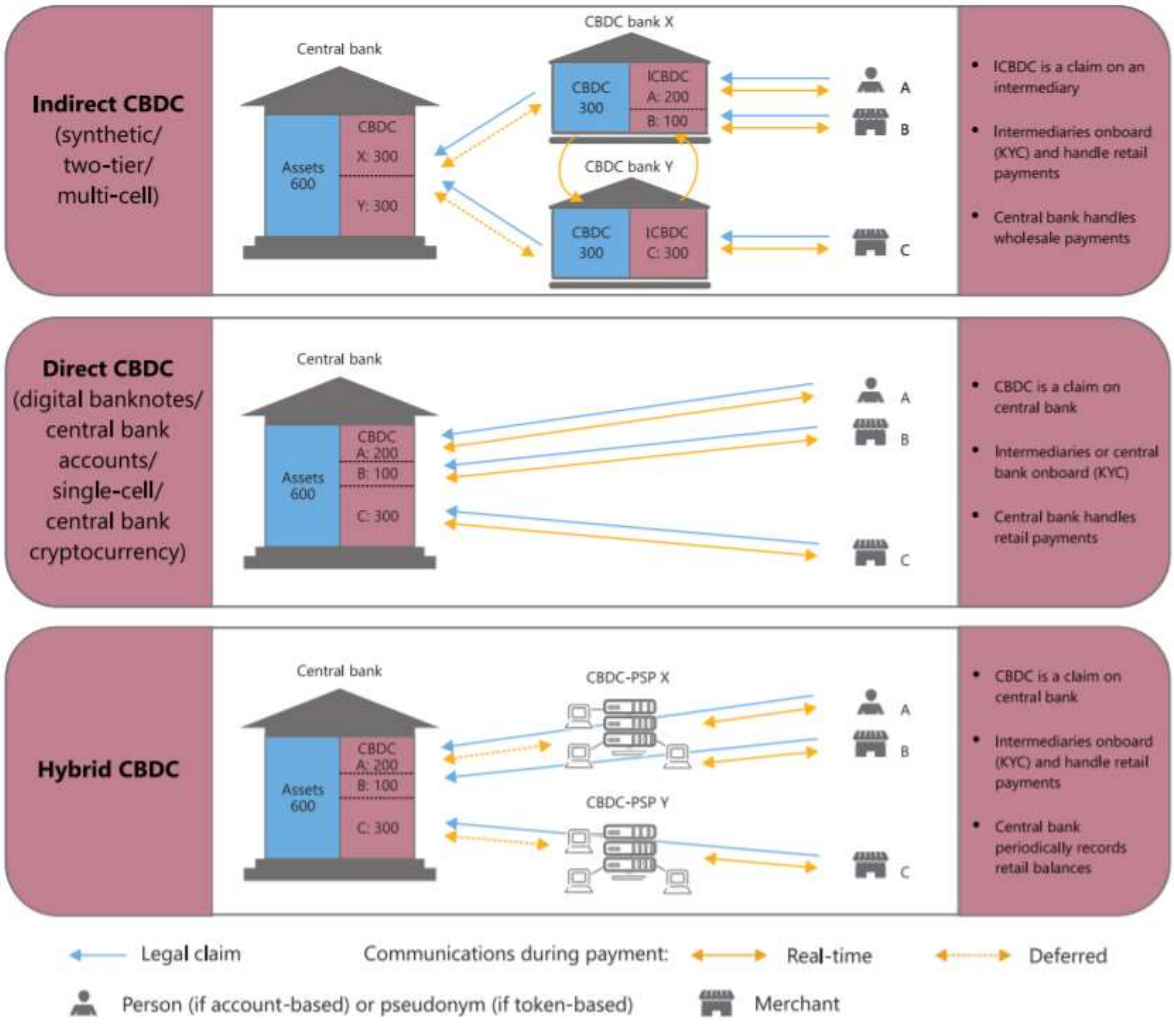

Figure 2.2 Comparison between CBDC architecture

Source: Auer & Böhme (2020)

[15] However, the KYC could be handled by intermediaries (Auer & Böhme, 2020b)

Hybrid CBDC is a merging between direct and indirect architecture, CBDC will be the direct claim of the central bank and intermediaries will handle KYC and retail payment (Auer & Böhme, 2020b). The central bank is the only authority that can issue or destroy CBDC while letting intermediaries handle interaction with the people (Calle & Eidan, 2020). An example of architecture that is identical with hybrid CBDC can be seen in Bank of England exploration[16]. In their discussion paper, Bank of England (2020a) designed a CBDC that the central bank functions as the core ledger, while the API will allow chosen intermediaries to be connected with a core ledger, then the intermediaries would manage all of the interaction with people and provide user-friend interfaces between users and ledger.

2.3.6 Ledger System (Centralized Ledger Technology vs Decentralized Ledger Technology)

Centralized Ledger System (CLT) is a ledger system that is created, controlled, and maintained by a central authority (Inghirami, 2019; Morgan, 2018). The central authority is responsible for ledger maintenance, asset transfer recording, and the invoice of the validated transaction (Zetzsche et al., 2017). All of the parties will reconcile their local database with a centralized ledger (World Bank, 2017). The authority is reflected as the most trusted guarantor of the entire financial system that can bring credibility in fund transfer records (Athanassiou, 2017). The transaction in CLT has involved the two parties which are the payer and payee, then each of the parties' ledgers will record the transaction by debiting and crediting each other. The bank will interfere with the centralized ledger to manage the transaction flow using the double-entry accounting principle, thus reflecting their truth perspective (Casey & Vigna, 2018; Laroiya et al., 2020; Lemma, 2020). CLT also has high efficiency due to its high transaction frequency and lower energy consumption (Rejeb & Keogh, 2021). For example, centralized VISA can process up to 56,000 transactions per second but Bitcoin that used decentralized architecture only can process up to 7 transactions per second (Drašković, 2018). CLT also allow central bank to easily control and coordinate as the small number of servers (Allen et al., 2020). However, CLT can conduct transaction forgery, transaction reversal, and censorships, which create an opportunity for illicit activities (Ainsworth & Magauran,

16 ibid

2018; Mainelli & Smith, 2015). It also carries the "single point of failure" risk, especially when an outage occurred[17] (Allen et al., 2020)

Meanwhile, DLT is a technology that enable us to record and share the data across multiple data ledgers (World Bank, 2017). This technology allows the ledger to be distributed, shared, and synchronized across the distributed network, so everyone can get a copy of it (Hasib, 2019). Account creation is also more seamless in DLT due to its improved identity verification and integration with IoT, then transform unbanked people, thus promoting financial inclusion (Barr et al., 2021; Farahani et al., 2021; Zarrin et al., 2021). DLT enable us to extend by using blockchain technology. Blockchain is a data structure that used in distributed ledgers which transmit and stores data in "blocks" that connected each other by a digital "chain" (World Bank, 2017). Blockchain and DLT are quite similar, both of them able to record the information and distribute the information across the network, but they are not equivalent (Chandler, 2019). Blockchain mechanism needs consensus to validate each transaction before it can form a "block" and "chain" (Ozdayi et al., 2020). Blockchain creates a block based on each validated transaction, then, every block that has been created will create a chain that is linked to the previous block hash and got time-stamped[18]. Any alteration will change the block hash and the whole chain will alert due to the desynchronization of block hash, in other words, its mechanism makes blockchain to be immutable and better transparency, thus hard to tamper with (Agrawal et al., 2021; Politou et al., 2019). Its attributes also could increase public trust because it can't be manipulated (Tong, 2021). Due to its immutability, the longer created chains will make the blockchain more resilient from the cyberattack (Narayanan et al., 2016). Blockchain implementation also allow us to conduct offline transaction through NFC (Igboanusi et al., 2021). However, we could not alter the transaction and can't revise the transaction if there any mistakes (Allen et al., 2020; Daian et al., 2019; Doweck & Eyal, 2020)

[17] One of the options to mitigate that risk is applying geo-replication in the system, so it can be easily recovered when one of the systems is down. (Allen et al., 2020).

[18] Usually, the method of securing decentralized is using Proof of Works. This is the part of adding a new block into the blockchain. The block will be summoned to life by the operator (miners). A new block will be accepted when the operator comes up with the new winning Proof of Works (Hertig, 2020)

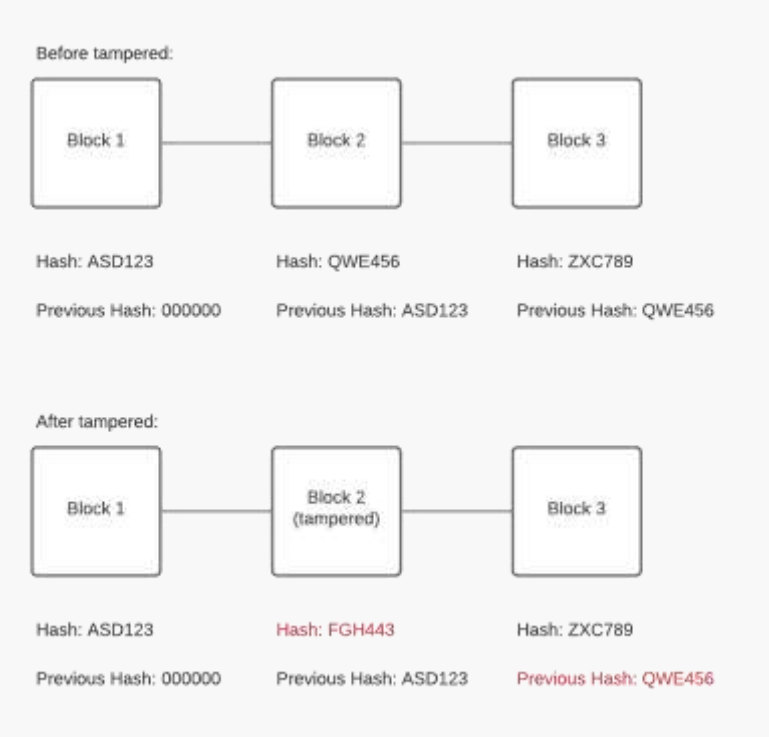

Figure 2.3 Blockchain mechanism

Source: Adapted from Nakamoto (2008)

Blockchain immutability attribute carries a huge consequence of energy consumption, each block creation requires some miners to validate its transaction, while the mining activities consume huge electricity, which is create more pollution[19] (Ghosh & Das, 2020). Meanwhile, DLT without using blockchain technology not consume much energy due to the absence of miners (Marco Polo Network, 2018). Aside from energy consumption, there is also another problem in CBDC implementation about the reward formulation for the operator (Allen et al., 2020), the central bank should calculate the optimal incentive for the operator so it could make longer chain due to the more attracted operator.

2.3.7 Scope (Domestic vs Cross-Border)

Domestic scope of the transaction means the payment where the transaction is respectively debited and credited in the same currency (Bech & Garratt, 2017). Currently, most of the CBDC development focuses on domestic scope for further investigation about economic and practicality before they advanced into cross-border (BIS et al., 2021). Also, based on the survey, most of the emerging economic countries are focusing on

19 For example, Malone & O'Dwyer (2014) found out that Bitcoin mining consume around 5 gigawatt (same amount of Ireland electric consumption in early 2014)

domestic uses rather than cross-border, meanwhile, advanced economics country has more motives. (Auer, Haene, et al., 2021). Both of domestic and cross-border CBDC also has concern to maintain user privacy (Zhang & Huang, 2021) On contrary, the cross-border scope is the payment where the transaction is respectively debited and credited in a different currency (Bech et al., 2020). Cost, speed, access, and transparency are the main critical concern of cross-border payment (Financial Stability Board, 2020). Cross-border CBDC could promote interoperability that has potential benefits such as fewer intermediaries, better efficiency, enhanced integration, enhanced compatibility, improved security, and mitigation of cross-border currency risk (Auer, Haene, et al., 2021; BIS, 2021c; Choi et al., 2017). Cross-border CBDC also has more concern on its transparency because AML/CFT become a nation measure of cross-border payment (FATF, 2021). Central bank also indicates another important concern such as ease of settlement, cyber security, and emergence global stablecoins (Auer, Boar, et al., 2021). Prior to CBDC, SEPA (Single Euro Payment Area) in European Union is one of the efforts to reduce the transaction cost of cross-border payment (Auer, Haene, et al., 2021). SEPA successfully create efficient cross-border payment by removing domestic and cross-border transaction (European Central Bank, 2019). However, security and resilience become more complex due to the involvement of several jurisdictions (BIS et al., 2021). Also, due to interlinkages, cross-border scope has more risk and chance of bank disintermediation (Chau & Dickinson, 2015). According to Auer et al. (2021), there are three approaches to achieve cross-border payment interoperability on CBDC :

Model I: mCBDC Arrangement Based on Compatible CBDC System

The compatible CBDC system approach is a system where private companies will handle the transfer between CBDC and they will get benefit from compatibility measures (Auer & Böhme, 2020b). The governance, rulebook, infrastructure, and criteria of participation will be defined by the system. But the standard of those aspects needs to be coordinated so it can simplify the KYC and transaction processes. This is important because if it's not well coordinated, it can take a long time like when coordinating participants to move to straighten legal frameworks in the complex market (Japan Ministry of Finance, 2020). Moreover, the compatibility of legal is one of the factors that cause friction in cross-border payment. Since this includes private companies, there will be competition among them. This competition will lead to innovation that can make CBDC be faster, cost less, and transparent (CPMI, 2018b).

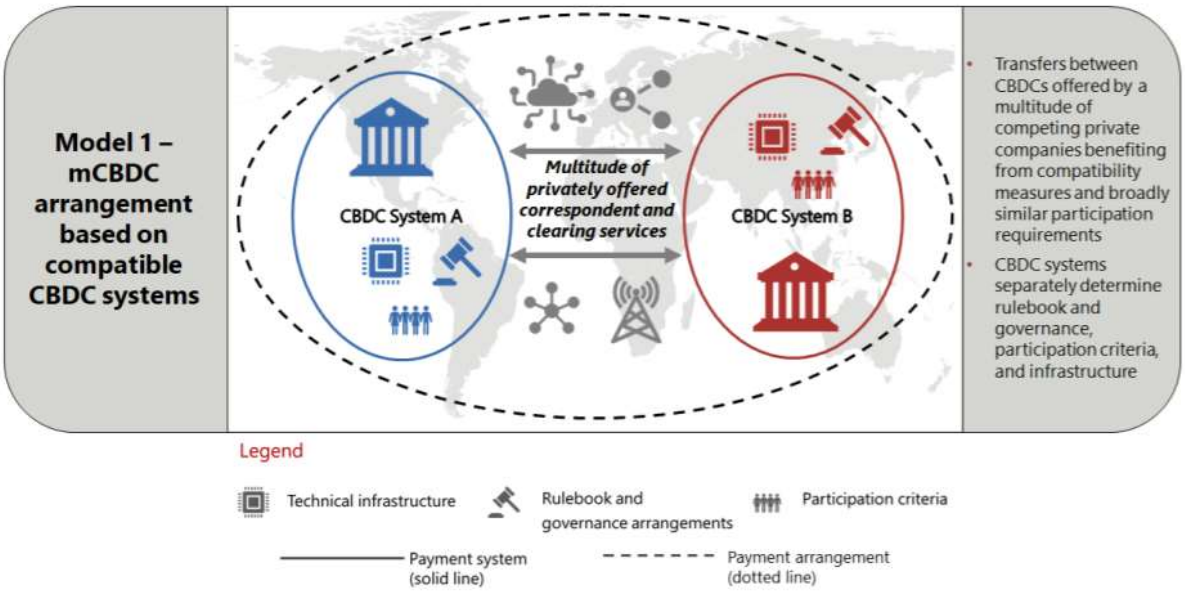

Figure 2.4 Model I: mCBDC Arrangement Based on Compatible CBDC System

Source: Auer et al. (2021)

Model II: mCBDC Arrangement Based on Interlinked CBDC System

An interlinked CBDC system is a system where both countries need to align their systems, such as a common clearing mechanism or shared technical interface (Auer, Haene, et al., 2021). A common clearing mechanism means linking the system through the chosen account of settlement, meanwhile, a shared technical interface allows the transaction to make payment to other countries, synchronize, and mitigate the risk of settlement with the support of the contractual agreement. The central bank is also able to hold other countries CBDC, and vice versa (Bank of Canada et al., 2018)

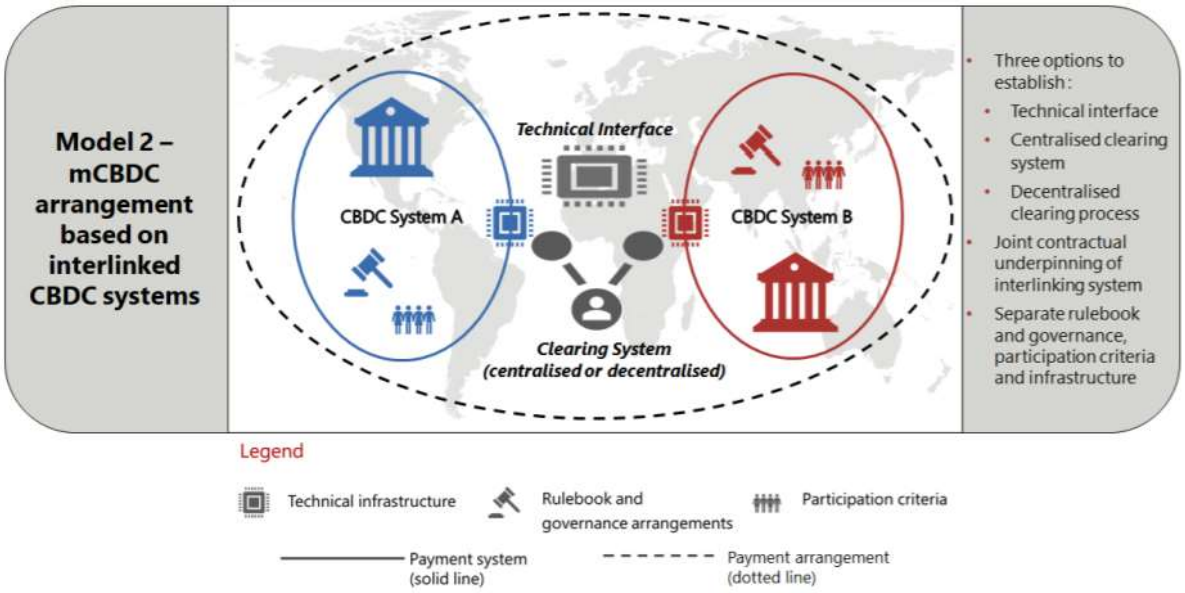

Figure 2.5 Model II: mCBDC Arrangement Based on Interlinked CBDC System

Source: Auer et al. (2021)

Model III: Single mCBDC Multi-currency System

This approach is more like the central bank being unified into one system including multiple CBDC. This is because the participant agrees to create a single rulebook, the requirement of participation, and infrastructure (Bech et al., 2020). This approach will enhance the efficiency and functionality but it creates a hurdle in their governance. This approach is compatible with both retail and wholesale CBDC. Retail CBDC will focus on volume and wider participation, while wholesale CBDC focuses on higher value and real-time payment. But there is a constraint in this approach when it comes to wider implications like monetary policy, financial stability, and payment policy. Central banks need to assess if they are willing to remove some of the governance to align with the multiple CBDC agreement (Auer, Haene, et al., 2021). Negotiation about this will be a huge constrain for each central bank to reach a consensus

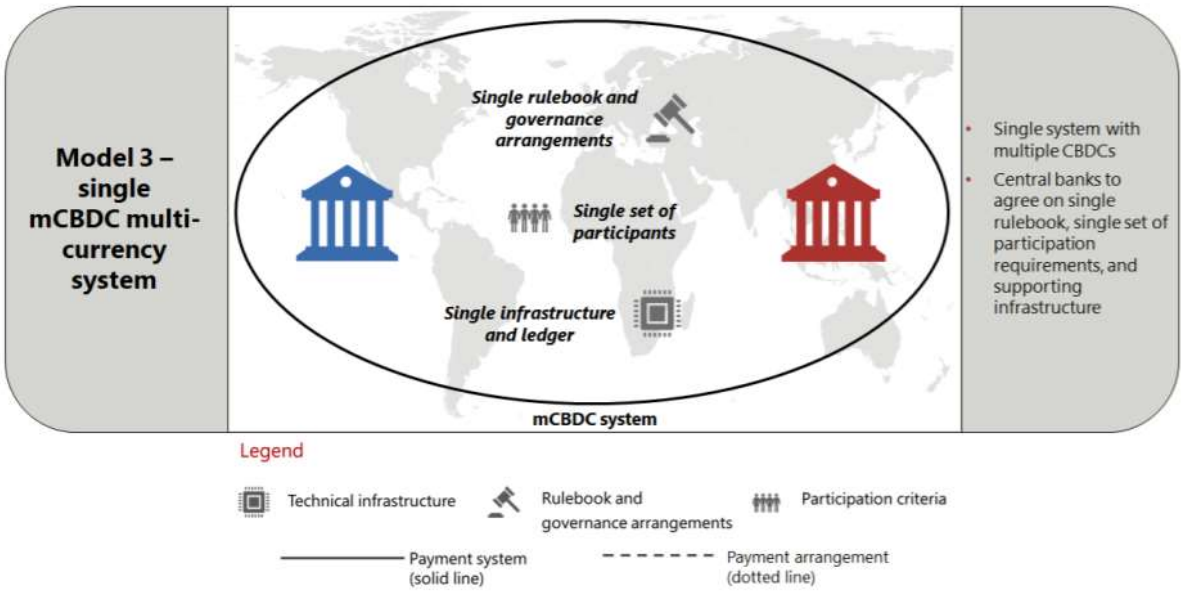

Figure 2.6 Model III: Single mCBDC Multi-currency System

Source: Auer et al. (2021)

2.4 Lesson Learned from CBDC Development

There is numerous CBDC development that has been conducted across the world ranging from the research phase to live implementation. Therefore, their output could be used as a lesson for this research so the optimal CBDC design would be robust. Legal aspects are one of the concerns that must be looked at in CBDC development, as regulatory amendment may be required in some countries depending on its jurisdiction (Morales-Resendiz et al., 2021; Townsend, 2019). According to (Riksbank, 2021a) in the pilot testing, Sweden found out that Riksbank as the central bank must be considered as guarantor of e-krona value, even though there are no intermediaries in the e-krona system. Also, Sweden must create a rule to regulate how much information that could be extracted from the transaction since its related to data privacy. E-krona itself also must be considered as a promissory note in a digital form in their jurisdiction. China also faces the problem regarding data privacy, it is still not clear how people (as a CBDC user) settle a problem when there is an issue of misused or fraudulence (Jiaying Jiang & Lucero, 2021)

Ensuring efficiency also becomes a concern that must be learned from CBDC development (Morales-Resendiz et al., 2021). Before massive CBDC development, Ecuador had already released its own digital currency namely dinero electrónico. However, due to its inefficiency against the private sector, people tend to use private

digital money rather than dinero electrónico, thus Ecuador canceled its digital currency due to the loss in the competition (Arauz et al., 2021).

System failure such as outage is unavoidable in the technology. One idea is using a token-based payment system that enables us to conduct an offline transaction (BIS, 2020). Sweden tries to assess the alternative methods for e-krona when there are any disruptions in energy provision, thus they try to find out the design that makes e-krona able to conduct an offline transaction (Armelius, Guiborg, et al., 2020). China also tries to provide offline transaction solutions by implementing NFC on its digital wallet (Chow & Eckert, 2021). Meanwhile, Uruguay uses USSD as a solution to conduct transactions offline (Bergara & Ponce, 2018)

Kudrycki (2021) argues that many CBDC research and development have a few concerns about interoperability, whereas, limited interoperability could make slow digital financial services. Meanwhile, sufficient interoperability in CBDC could ensure the seamless funds flow between the payment system and able to reach a broader payment landscape, resilience, payment diversity, financial inclusion, improving cross-border payment, and supporting privacy (BIS, 2021c).R3 Corda (2021) argues that the bare minimum of reaching interoperability is proof that the transaction has taken place that is facilitated by finality at the smart contract level.

The adoption process including onboarding, financial education, and incentive becomes a barrier in CBDC distribution. For example, the Bahamas pain point is the costly onboarding due to the archipelago geographic access barriers (Morales-Resendiz et al., 2021). The key to successful adoption lies in how easy the onboarding and strong push to reduce cash usage (BIS, 2021d). Ease of onboarding also being one of the perquisites of well-functioning CBDC (Allen et al., 2020). Therefore, it could be learned that adoption is an important concern in CBDC implementation

To have a robust CBDC design, it could be learned that CBDC must follow the Principle of Financial Market Infrastructure (PFMI) (Morales-Resendiz et al., 2021). PFMI is consisting of 24 principles that aimed to strengthen financial market infrastructure and support financial stability (CPSS, 2012). Allen et al. (2020) argue that PFMI could become a measure of the governance, operational, and financial ability of their CBDC implementation. Bank of England (2021) also argue that PFMI could be the assessment of risk in financial market infrastructure in the presence of CBDC implementation.

2.5 Limitation in CBDC Implementation

CBDC needs to be carefully drafted frameworks, clear concepts, as well as a good strategy, which are at least equally important to exploit the full potential of CBDC (Koumbarakis & Dobrauz-saldapenna, 2019). There are some aspects that must be concern as an insight before implementing CBDC:

2.5.1 Digital Divide

Digital Divide occurs when there is a gap between either region or demographic that already digitalized and not (Taylor, 2021). It refers to the accessibility to internet connection, devices, and any other technologies. Meanwhile, effective CBDC implementation requires the adequate infrastructure, such as internet coverage, devices, digital literacy, and common digital adoption (Didenko & Buckley, 2021; Lee, 2020; Pantuliano & Tyson, 2021). The internet users around the world is only 60.1 percent in 2021 (Kemp, 2021). The global smartphone penetration also still reaches 78.05 percent in 2021 (O'Dea, 2021). Those gaps implies that there still some concern about digital divide that become the limitation of CBDC implementation. While finding the solutions of digital divide, the central bank could implement broad range of devices that can be used by CBDC (European Central Bank, 2020). BIS (2021d) also implies that offline accessibility is required and relevant for the area that have limited internet coverage. Thus, CBDC design should able to conduct in both online and offline situation.

2.5.2 Weak Cyber Security

Cyber security could be defined as information protection of electronic system from theft or damage (Schatz et al., 2017). There will always be an effort to exploit the technology for personal gain, which means the risk of cyberattack is always exist (Australian Computer Society, 2016). However, the issue of cyberattack towards fintech is keep raising since 2017 (Sadlawokski & Sobieraj, 2017), which means, cyber security of CBDC being a limitation for its implementation. Moreover, emerging markets are tend to have more exposure to cyberattack, especially if the government has weak effort in handling sensitive data (KPMG, 2015). For example, Singapore Redmart, Thailand hospital, Singapore ST Engineering Aerospace, Indonesia Tokopedia are major known of cyberattack incident in 2020 (INTERPOL, 2021). Indonesia also the 2nd most vulnerable against cyber-attack after India in 2020 (National Cyber and Crypto Agency (BSSN),

2021). Moreover, World Bank (2021a) in Beyond Unicorn publication said that strengthening cyber security still being a main priority to be fixed. Therefore, weak cyber security could be the limitation of CBDC implementation because the responsibilities of CBDC as the carrier high-value target consisting of public identity information (Minwalla, 2020)

2.5.3 Costly CBDC Infrastructure

CBDC infrastructure is costly because it needs to develop customer interface, front-end wallet, choose and maintain technology, supervise transactions, promote AML, and prevent CFT (Adrian & Griffoli, 2019). Bank of England also still assess the CBDC issuance with their treasury (Central Banking Newsdesk, 2021a). The infrastructure cost of CBDC infrastructure could be allocated to anything else as long as it brings prosperity. To have the public sector handle technology such as CBDC will be irrelevant and costly, as the private sector keeps innovating (Adrian, 2020). Therefore, public-private partnership is more cost-saving in the procurement of CBDC infrastructure. It was also applied by most of the countries that developing CBDC. Moreover, it makes us able to integrate the data for KYC and AML with private entities. We have either state-owned enterprise banks or fintech companies on Indonesia Fintech Association or other private banks to cooperate with. With this scheme, the central bank can be the focus on building the most efficient and effective system rather than the procurement itself. Most of the countries that develop CBDC use this scheme also. The challenge is either the central bank and government need to give good bargaining in this partnership to ensure smooth procurement and deployment.

2.5.4 Inequal Financial Inclusion

Indonesia still has 76.19 percent of financial inclusion (Otoritas Jasa Keuangan, 2019). Currently, distribution on Indonesia's financial inclusion is concentrated in the west part of Indonesia while the east part of Indonesia is less concentrated. This is in accordance with Asosiasi Penyelenggara Jasa Internet Indonesia (2020) findings that the east part of Indonesia still has bad internet coverage. Promoting financial inclusion will be a wise choice because it will make CBDC distribution easier. Moreover, promoting financial inclusion also increases economic growth, reduces poverty, and reduces inequality (Erlando et al., 2020). Therefore, Indonesia must consider the connectivity by pushing the internet infrastructure so the CBDC distribution will be successful

3. Data and Methodology

3.1 DSGE Approach

3.1.1 Assumption

Our model economy is populated by seven classes of agents: a continuum of identical households of measure unity indexed by $h \in [0,1]$, a retail firm or final-good producing firm, a continuum of wholesale firms or intermediate-good producing firms indexed by $j \in [0,1]$, a capital-producing firm, a commercial bank, the central bank as a monetary authority and the government.

The basic structure of our DSGE model is depicted in closed economy New Keynesian framework by Getler & Karadi (2011), Primus (2017), and Gross & Schiller (2020, 2021)

Household consume and supply labour to wholesale firms, receive wage, choose the real levels of cash, deposits, CBDC and government bonds to hold at the beginning of the period, and pay lumpsum tax to the government. Households also receive dividends from firms and the bank. Retail firm aggregates imperfectly substitutable intermediate goods into a single final good which is used for consumption, investment or government spending. The final good is sold at a perfectly competitive price. Wholesale firms use the labour provided by households and capital to produce a unique good that is sold on the monopolistically competitive market. Wages are fully flexible and adjust to clear the market. Capital-producing firm purchases the final good for investment and combines it with existing capital stock to produce new capital goods. Commercial bank is owned by households. The bank supplies credit to wholesale firms to finance their short-term working capital needs, supplies credit to the capital-producing firm for investment financing, pays interest on household deposits and central bank loans, and holds minimum reserves against deposits at the central bank and gets remuneration.

The central bank regulates the commercial bank and sets its policy interest rate using a Taylor-type rule and supplies all the credit demanded by the bank at the prevailing refinance rate. The government offers bonds, receives tax payments and makes spending

In some aspects we follow approaches developed in previous researches by others and in different standpoints we make few extensions. Our model has the following features:

1. We consider a money-in-utility intertemporal welfare function to be maximized by households. The presence of cash in addition to bank deposits and CBDC is slightly extend the one by (Gross & Schiller, 2021). The cash also appears in the budget constraint.
2. We decompose the total consumption by households into those using cash and CBDC. The price of consumption goods is also differentiated according to cash and CBDC.
3. Consumption goods purchases by using cash and CBDC are conducted by incorporating a proportional transaction cost. This assumption widens the transaction activities in (Gross & Schiller (2021) but conforms with one by (Barrdear & Kumhof, 2017)
4. In the profit maximization of wholesale firm we adopt the so-called Calvo-Yun price setting, where firms have a certain probability of either keeping the price fixed in the next period or optimally determining its price
5. Banks hold their funds in central bank reserves in the form of cash and CBDC, both for required and excess reserves. Central bank pays interest on reserve balances.
6. Banks supply loans to firms in combination of cash and CBDC
7. Similar to Gross & Schiller (2021), the nominal interest rate on CBDC follows the interest rate of central bank funding considering the financial stress expressed as the percentage deviation of banks equity from steady state. This rule is intended to disincentivize CBDC accumulation in a crisis
8. Government bonds are held by banks, central bank, and households.
9. To quantify the effect of disruptions by economic shocks, our model is equipped with a number of shock generators, namely technology shock, and the shock on Taylor rule of interest rate

3.1.2 The Model of Economy

3.1.2.1 Household

In this model, the economy is populated by a continuum of households indexed by $h \in [0,1]$ whose problem is to maximize a particular intertemporal welfare function. To this end, a money-in-utility function proposed by Sidrauski (1986) and in the form of the constant relative risk aversion (CRRA) utility function is adopted. The lifetime utility function U^H is additively separable into consumption of goods $C_{h,t}$, supply of working

hours $L_{h,t}$, and saving in the form of bank deposits $D_{h,t}$, money holding in cash (real money balance) $M_{h,t}$, and digital money holding in CBDC $E_{h,t}$. Each household h wants to maximize the following expected utility:

$$U^H = \mathbb{E}_0 \sum_{i=0}^{\infty} \beta^i \left(\frac{C_{j,i}^{-\sigma}}{1-\sigma} + \frac{\alpha_e \left(E_{j,i}/P_i\right)^{1-\eta_e}}{1-\eta_e} + \frac{\alpha_m \left(M_{j,i}/P_i\right)^{1-\eta_m}}{1-\eta_m} + \frac{\alpha_d \left(D_{j,i}/P_i\right)^{1-\eta_d}}{1-\eta_d} + \frac{\alpha_l L_{j,i}^{1+\varphi}}{1+\varphi} \right), \tag{2.1}$$

where $\mathbb{E}_0$ stands for the rational expectations operator conditional on the information set at time zero. In (2.1), $\beta \in (0,1)$ is the intertemporal discount factor, $\sigma \in (0,1)$ is the relative risk aversion coefficient, α_e, α_m, $\alpha_d > 0$ are relative utility weights or preference parameters of CBDC, cash, and bank deposits, φ is coefficient relates to Frisch elasticity of labor supply, and $\eta_d, \eta_m, \eta_e > 0$ are coefficients relate to elasticity of bank deposits, cash, and CBDC. We may extend the form of household's utility function by introducing wealth in the form of government bonds $B_{h,t}^H$ as discussed by, for instance, Michaillat & Saez (2021). However, this extension modifies the properties of the New Keynesian IS curve, where the interest rate is now negatively related to output instead of being constant, equal to the time discount rate.

Households are assumed to consume goods, invest money, pay taxes, and receive wages for their labor supplied. Households also own the firms and the bank, and therefore receive dividends and profits sharing. Decisions made by households must match the following budget constraint:

$$\begin{aligned} P_t\left(C_{h,t} + INV_{h,t}\right) + E_{h,t} + M_{h,t} + D_{h,t} + TAX_{h,t} \\ = W_t L_{h,t} + R_t^K K_{h,t} + (1 + I_{t-1}^E) E_{h,t-1} + M_{h,t-1} + (1 + I_{t-1}^D) D_{h,t-1} \\ + \Pi_{h,t}^{FB}. \end{aligned} \tag{2.2}$$

The terms on the left-hand side of (2.2) summarize the use of economic resources by households and those on the right-hand side indicate the economic resources. In (2.2), P_t is the general price level, $INV_{h,t}$ is level of investment, $TAX_{h,t}$ is the lump sum tax, W_t

is the level of wages, $K_{h,t}$ is the capital stock, R_t^K is the return on capital, I_t^E is the nominal interest rate of CBDC, I_t^D is the nominal interest rate of bank deposits, and $\Pi_{h,t}^{FB}$ is the profit (dividend) from firms and bank. An additional equation represents the capital stock dynamics is

$$K_{h,t+1} = INV_{h,t} + (1-\delta)K_{h,t}, \tag{2.3}$$

where δ is the depreciation rate of physical capital. Substitution (2.3) into (2.2) provides

$$\begin{aligned} P_tC_{h,t} + P_tK_{h,t+1} - P_t(1-\delta)K_{h,t} + E_{h,t} + M_{h,t} + D_{h,t} + TAX_{h,t} \\ = W_tL_{h,t} + R_t^KK_{h,t} + (1+I_{t-1}^E)E_{h,t-1} + M_{h,t-1} + (1+I_{t-1}^D)D_{h,t-1} \\ + \Pi_{h,t}^{FB}. \end{aligned} \tag{2.4}$$

The Lagrange function $\mathcal{L}^H$ of the problem is given by

$$\mathcal{L}^H = \beta^t(U_t^H + \Lambda_t^H H_t) + \beta^t\mathbb{E}_t(U_{t+1}^H + \Lambda_{t+1}^H H_{t+1}), \tag{2.5}$$

where Λ_t^H is the Lagrange multiplier, while U_t^H and H_t are given as follow:

$$U_t^H = \frac{C_{h,t}^{-\sigma}}{1-\sigma} + \frac{\alpha_e\left(E_{h,t}/P_t\right)^{1-\eta_e}}{1-\eta_e} + \frac{\alpha_m\left(M_{h,t}/P_t\right)^{1-\eta_m}}{1-\eta_m} + \frac{\alpha_d\left(D_{h,t}/P_t\right)^{1-\eta_d}}{1-\eta_d} + \frac{\alpha_l L_{h,t}^{1+\varphi}}{1+\varphi},$$

$$\begin{aligned} H_t = P_tC_{h,t} + P_tK_{h,t+1} - P_t(1-\delta)K_{h,t} + E_{h,t} + M_{h,t} + D_{h,t} + TAX_{h,t} - W_tL_{h,t} - R_t^KK_{h,t} \\ - (1+I_{t-1}^E)E_{h,t-1} - M_{h,t-1} - (1+I_{t-1}^D)D_{h,t-1} - \Pi_{h,t}^{FB}. \end{aligned}$$

The Lagrange function $\mathcal{L}^H$ should be maximized with respect to consumption $C_{h,t}$, CBDC holding $E_{h,t}$, cash holding $M_{h,t}$, deposit holding $D_{h,t}$, labor time $L_{h,t}$, and capital stock $K_{h,t+1}$. Respectively we obtain the following relations:

$$C_{h,t}^{-\sigma} = -\Lambda_t^H P_t, \tag{2.6}$$

$$\alpha_e \left(\frac{E_{h,t}}{P_t}\right)^{-\eta_e} = -\Lambda_t^H + \beta(1 + I_t^E)\mathbb{E}_t \Lambda_{t+1}^H, \tag{2.7}$$

$$\alpha_m \left(\frac{M_{h,t}}{P_t}\right)^{-\eta_m} = -\Lambda_t^H + \beta \mathbb{E}_t \Lambda_{t+1}^H, \tag{2.8}$$

$$\alpha_d \left(\frac{D_{h,t}}{P_t}\right)^{-\eta_d} = -\Lambda_t^H + \beta(1 + I_t^D)\mathbb{E}_t \Lambda_{t+1}^H, \tag{2.9}$$

$$-\alpha_l L_{h,t}^{\varphi} = \Lambda_t^H W_t, \tag{2.10}$$

$$\Lambda_t^H P_t = \beta \mathbb{E}_t \Lambda_{t+1}^H ((1 - \delta)P_{t+1} + R_{t+1}^K. \tag{2.11}$$

Note that terms in the right-hand side of (2.6)-(2.10) are independent of index h. It means that expressions in the left-hand side are the same across households. Thus, from now on, we will drop the index h from the expression. From (2.6) we have $\Lambda_t^H = -C_t^{-\sigma}/P_t$ and from (2.10) we obtain $\Lambda_t^H = -\alpha_l L_t^{\varphi}/W_t$. By equating these two equations we get the following condition:

$$\alpha_l C_t^{\sigma} L_t^{\varphi} = \frac{W_t}{P_t}. \tag{2.12}$$

Substitution $\Lambda_t^H = -C_t^{-\sigma}/P_t$ into (3.11) yields

$$\left(\frac{\mathbb{E}_t C_{t+1}}{C_t}\right)^{\sigma} = \beta \left(1 - \delta + \mathbb{E}_t \frac{R_{t+1}^K}{P_{t+1}}\right), \tag{2.13}$$

and substitution $\Lambda_t^H = -C_t^{-\sigma}/P_t$ into (2.7)-(2.9) gives, respectively, the demand for CBDC, cash, and bank deposits:

$$\alpha_e \left(\frac{E_t}{P_t}\right)^{-\eta_e} = \frac{C_t^{-\sigma}}{P_t} - \beta(1 + I_t^E)\mathbb{E}_t \frac{C_{t+1}^{-\sigma}}{P_{t+1}}, \tag{2.14}$$

$$\alpha_m \left(\frac{M_t}{P_t}\right)^{-\eta_m} = \frac{C_t^{-\sigma}}{P_t} - \beta \mathbb{E}_t \frac{C_{t+1}^{-\sigma}}{P_{t+1}}, \tag{2.15}$$

$$\alpha_d \left(\frac{D_t}{P_t}\right)^{-\eta_e} = \frac{C_t^{-\sigma}}{P_t} - \beta(1 + I_t^D)\mathbb{E}_t \frac{C_{t+1}^{-\sigma}}{P_{t+1}}. \tag{2.16}$$

Therefore, the first order conditions of the lifetime utility maximization faced by households are given by equations (2.12)-(2.16).

3.1.2.2 Retail Firm

Suppose that at time t wholesale firm j produces $Y_{j,t}$ units of intermediate goods and there is a continuum of intermediate goods over the unit interval $[0,1]$. These intermediate goods are CES aggregated by a retail firm (final good producer) to produce Y_t. The production technology for assembling intermediate goods to produce the final good is given by the standard Dixit-Stiglitz technology (Dixit & Stiglitz, 1977):

$$Y_t = \left(\int_0^1 \left(Y_{j,t}\right)^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}} dj, \tag{3.1}$$

where $\theta > 1$ represents the elasticity of substitution between intermediate goods. With the nominal price of a final good is denoted by P_t and that of an intermediate good j is denoted by $P_{j,t}$, the price of each intermediate good is taken as a given by retail firms. Therefore, the representative retail firm chooses the quantities of intermediate goods such that maximize its profits:

$$U^{RF} = P_t Y_t - \int_0^1 P_{j,t} Y_{j,t}\ dj, \tag{3.2}$$

where the first term in the right-hand side of (3.2) is the total revenue from selling final goods and the second term is the total cost of buying intermediate goods. Substituting the aggregator technology (3.1) into (3.2) leads to the following first order condition of profit maximization with respect to $Y_{j,t}$:

$$Y_{j,t} = \left(\frac{P_t}{P_{j,t}}\right)^{\theta} Y_t. \tag{3.3}$$

Equation (3.3) accounts the demand level of intermediate good j, which is directly proportional to aggregate demand Y_t and inversely proportional to its relative price level P_t. This optimal quantity will be used in the optimization process faced by wholesale firms.

Since retail firms are perfectly competitive, where there are many firms producing the same products that none of the firms can have enough ability in the long-run to influence the economy, then a zero profit should be imposed. By setting $U^{RF} = 0$ in (3.2) and using (3.3) we have

$$P_t Y_t = \int_0^1 P_{j,t} Y_{j,t}\ dj$$

$$P_t = \int_0^1 P_{j,t} \left(\frac{P_t}{P_{j,t}}\right)^{\theta}\ dj$$

$$P_t^{1-\theta} = \int_0^1 P_{j,t}^{1-\theta}\ dj,$$

so that the price of retail goods is obtained as follows:

$$P_t = \left(\int_0^1 P_{j,t}^{1-\theta}\right)^{\frac{1}{1-\theta}}\ dj. \tag{3.4}$$

Equation (3.4) represents the mark-up rule for final goods.

3.1.2.3 Wholesale Firm

Each wholesale firm j produces a perishable intermediate good which is sold on a monopolistically competitive market. To produce these goods, each firm rents capital $K_{j,t}$

at the price R_t^K from the capital good producer and combines it with labor from households $L_{j,t}$. Each wholesale firm has a Cobb-Douglas production function:

$$Y_{j,t} = A_t K_{j,t}^{\alpha} L_{j,t}^{1-\alpha} \tag{4.1}$$

where $K_{j,t}$ is the amount of capital rented by wholesale firm j from capital market, L_j is the number of working hours supplied by households to firm j, $\alpha \in (0,1)$ is the elasticity of output with respect to capital, and A_t is the productivity or technology shock, which governed by the following process

$$\ln A_t = \rho_a \ln A_{t-1} + \varepsilon_t^a, \tag{4.2}$$

where $\rho_a \in (0,1)$ is the persistence coefficient and $\varepsilon_t^a \sim N(0, \sigma_\varepsilon)$. By recalling that $\bar{A}$ is the steady state value of A_t, we may write (4.2) as $\ln A_t - \ln \bar{A} = \rho_a(\ln A_{t-1} - \ln \bar{A}) + \varepsilon_t^a$, and then

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a, \tag{4.3}$$

where a_t is the log-linearization of A_t. It is shown that A_t follows a first-order autoregressive process with persistence ρ_a.

Total wages should be transferred by wholesale firm j to household is $W_t L_{j,t}$. However, we assume that there is a possibility wholesale firm j can take short-term loans from commercial bank to pay part of wages in advance. The amount of the loan $Q_{j,t}^{IF}$ is given by

$$Q_{j,t}^{IF} = k_Q W_t L_{j,t}, \tag{4.4}$$

where $k_Q \in (0,1)$ is the portion of total wages borrowed from bank. As in Primus (2017), we also assume that short-term loans for working capital do not carry any risk and are therefore contracted at a rate that reflects only the marginal cost of borrowing from the central bank, I_t^{CB},

which is the refinance rate. Thus, k_Q can be seen as the strength of the cost channel. As we may write $W_t L_{j,t} = Q_{j,t}^{IF} + (1 - k_Q) Q_{j,t}^{IF}$, the wages claim faced by the wholesale firm is given by

$$(1 + I_t^{CB}) Q_{j,t}^{IF} + \left(1 - k_Q\right) W_t L_{j,t} = \left(1 + k_Q I_t^{CB}\right) W_t L_{j,t}. \quad (4.5)$$

Each of wholesale firm solves a two-stage optimization problem. First, the firm j takes the prices of the factors of production (return on capital R_t^K and wages W_t) as given and determines the amount of capital and labor that it will use to minimize its total production cost.

3.1.2.3.1 The Cost Minimization Problem

The total cost $TC_{j,t}$ to be minimized by the firm j consists of wages bill (4.5) and capital rent. Thus, the cost minimization problem is stated as minimize

$$TC_{j,t} = \left(1 + k_Q I_t^{CB}\right) W_t L_{j,t} + R_t^K K_{j,t} \quad (4.6)$$

subject to production function (4.1). The Lagrange function for this problem is defined as

$$\mathcal{L}_j^{IF} = \left(1 + k_Q I_t^{CB}\right) W_t L_{j,t} + R_t^K K_{j,t} + \Lambda_t^{IF} \left(Y_{j,t} - A_t K_{j,t}^{\alpha} L_{j,t}^{1-\alpha}\right), \quad (4.7)$$

where Λ_t^{IF} is the Lagrange multiplier. The first order condition with respect to $L_{j,t}$ and $K_{j,t}$ are respectively as follow:

$$\left(1 + k_Q I_t^{CB}\right) W_t - (1 - \alpha) \Lambda_t^{IF} A_t K_{j,t}^{\alpha} L_{j,t}^{-\alpha} = 0 \quad (4.8)$$

$$R_t^K - \alpha \Lambda_t^{IF} A_t K_{j,t}^{\alpha-1} L_{j,t}^{1-\alpha} = 0. \quad (4.9)$$

From the second equation (4.9) we have

$$\frac{R_t^K K_{j,t}}{\alpha L_{j,t}} = \Lambda_t^{IF} A_t K_{j,t}^{\alpha} L_{j,t}^{-\alpha},$$

and substitute it into the first equation (4.8) provides

$$\frac{K_{j,t}}{L_{j,t}} = \frac{\alpha\left(1 + k_Q I_t^{CB}\right) W_t}{(1-\alpha) R_t^K}. \tag{4.10}$$

Since none of the terms on the right-hand side of (4.10) depends on j, then, the capital-labor ratio will be the same across all firms, which in turn will be equal to the aggregate ratio

$$\frac{K_{j,t}}{L_{j,t}} = \frac{K_t}{L_t}.$$

From now on we will also drop the firm index j from the expression. We may have an expression of K_t from (4.10) as follows:

$$K_t = \frac{\alpha\left(1 + k_Q I_t^{CB}\right) W_t L_t}{(1-\alpha) R_t^K}. \tag{4.11}$$

And by substituting (4.11) into (4.6) we have the new expression of the total cost:

$$TC_t = \frac{1 + k_Q I_t^{CB}}{1-\alpha} W_t L_t. \tag{4.12}$$

Further, by (4.11) we may rewrite the production technology (4.1) as a function of one input:

$$Y_t = A_t \left(\frac{\alpha\left(1 + k_Q I_t^{CB}\right) W_t}{(1-\alpha) R_t^K} \right)^{\alpha} L_t,$$

or equivalently,

$$L_t = \frac{Y_t}{A_t} \left(\frac{\alpha\left(1 + k_Q I_t^{CB}\right) W_t}{(1-\alpha) R_t^K} \right)^{-\alpha}. \tag{4.13}$$

By substituting (4.13) into (4.12), the total cost becomes

$$TC_t = \frac{Y_t}{A_t}\left(\frac{\left(1+k_Q I_t^{CB}\right)W_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{R_t^K}{\alpha}\right)^{\alpha}. \quad (4.14)$$

Therefore, the marginal cost function MC_t is the derivative of the total cost function (4.14) with respect to the output Y_t:

$$MC_t = \frac{1}{A_t}\left(\frac{\left(1+k_Q I_t^{CB}\right)W_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{R_t^K}{\alpha}\right)^{\alpha}. \quad (4.15)$$

By (4.15) we can respectively rewrite (4.13) and (4.11) as follow:

$$L_t = (1-\alpha)\frac{MC_t}{1+k_Q I_t^{CB}}\frac{Y_t}{W_t}, \quad (4.16)$$

$$K_t = \alpha MC_t \frac{Y_t}{R_t^K}. \quad (4.17)$$

3.1.2.3.2 The Profit Maximization Problem

In the second stage, wholesale firm wants to maximize the real profits it gives back to households. Note that by (4.11) the number of working hours required for producing one unit of good is calculated as follows:

$$A_t K_t^{\alpha} L_t^{1-\alpha} = 1$$

$$A_t\left(\frac{\alpha\left(1+k_Q I_t^{CB}\right)W_t L_t}{(1-\alpha)R_t^K}\right)^{\alpha} L_t^{1-\alpha} = 1$$

$$A_t\left(\frac{\alpha\left(1+k_Q I_t^{CB}\right)W_t}{(1-\alpha)R_t^K}\right)^{\alpha} L_t = 1,$$

from which we get

$$L_t = \frac{1}{A_t}\left(\frac{\alpha\left(1+k_Q I_t^{CB}\right)W_t}{(1-\alpha)R_t^K}\right)^{1-\alpha}.$$

The optimal cost of producing one unit of good $TC_t(1)$ can then be obtained by substituting the above quantity into (4.12) yielding

$$TC_t(1) = \frac{1}{A_t}\left(\frac{\left(1 + k_Q I_t^{CB}\right)W_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{R_t^K}{\alpha}\right)^{\alpha}, \tag{4.16}$$

which is the same as (4.15). Expression (4.16), however, states that the marginal cost MC_t is nothing else than the optimal cost of producing one unit of good.

By this fact, the profit of wholesale firm j can be formulated as follows:

$$\Pi_{j,t}^{IF} = P_{j,t}Y_{j,t} - MC_t Y_{j,t}, \tag{4.17}$$

where the first term in the right-hand side of (4.17) is the total revenue and the second term is the total production cost. In addition to the stochastic discount factor β, wholesale firms will also discount future profits by ϕ. We also impose that the wholesale firms face the constraint that they can only adjust prices following a Calvo-type rule. The wholesale firm has a ϕ probability of keeping the price fixed in the next period and a $1-\phi$ probability of optimally determining its price. Hence (4.17) becomes

$$\Pi_{j,t}^{IF} = \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s (P_{j,t}Y_{j,t+s} - MC_{t+s}Y_{j,t+s}). \tag{4.18}$$

This profit function should be maximized subject to (4.3), which can be rewrite as

$$Y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\theta} Y_t. \tag{4.19}$$

Substitution constraint (4.19) into (4.18) gives

$$\Pi_{j,t}^{IF} = \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s (P_{j,t}^{1-\theta} P_{t+s}^{\theta} - P_{j,t}^{-\theta} P_{t+s}^{\theta} MC_{t+s}) Y_{t+s}, \tag{4.20}$$

and then the first order condition with respect to $P_{j,t}$ is

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s ((1-\theta) P_{j,t}^{-\theta} P_{t+s}^{\theta-1} + \theta P_{j,t}^{-\theta-1} P_{t+s}^{\theta-1} MC_{t+s}) Y_{t+s} = 0 \tag{4.21}$$

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \left(1 + \frac{\theta}{1-\theta} \frac{MC_{t+s}}{P_{j,t}}\right) = 0. \tag{4.22}$$

Thus, at time t wholesale firms choose $P_{j,t}$ so as to set a weighted average of the difference between marginal revenue and marginal cost to zero:

$$1 + \frac{\theta}{1-\theta} \frac{MC_{t+s}}{P_{j,t}} = 0 \Leftrightarrow P_{j,t} = \frac{\theta}{\theta - 1} MC_{t+s}. \tag{4.23}$$

We may also separate (4.22) to have a recursive expression of the price

$$\sum_{s=0}^{\infty} (\beta\phi)^s = \frac{\theta}{\theta - 1} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \frac{MC_{t+s}}{P_{j,t}}$$

$$\frac{P_{j,t}}{1-\beta\phi} = \frac{\theta}{\theta - 1} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s MC_{t+s}$$

$$P_{j,t} = \frac{\theta(1-\beta\phi)}{\theta - 1} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s MC_{t+s}.$$

At this point, the so-called Calvo-Yun price setting was exploited by many literatures to linearize (4.22) around a deterministic steady state with zero-inflation leading to the famous linear New Keynesian Phillips curve involving inflation and marginal costs. See, for instance, Gali & Monacelli (2005) and Monacelli (2005). However, in this work, without restricting attention to the case of log-linear dynamics around a zero-inflation steady state, we follow an approach by Fernandez-Villaverde & Rubio-Ramírez (2006) and proceed (4.21) as follows:

$$\sum_{s=0}^{\infty}(\beta\phi)^{s}\left(\frac{1-\theta}{P_{j,t}}\left(\frac{P_{j,t}}{P_{t+s}}\right)^{1-\theta}+\frac{\theta}{P_{j,t}}\left(\frac{P_{j,t}}{P_{t+s}}\right)^{-\theta}\frac{MC_{t+s}}{P_{t+s}}\right)Y_{t+s}=0$$

and then

$$\sum_{s=0}^{\infty}(\beta\phi)^{s}\left(\left(\frac{P_{j,t}}{P_{t+s}}\right)^{1-\theta}+\frac{\theta}{1-\theta}\left(\frac{P_{j,t}}{P_{t+s}}\right)^{-\theta}\frac{MC_{t+s}}{P_{t+s}}\right)Y_{t+s}=0. \qquad (4.24)$$

As we will show later, log-linearization over (4.24) will provide relation between the price of final good P_t, the price of intermediate good $P_{j,t}$, the marginal cost MC_t, and inflation rate π_t.

3.1.2.4 Capital Producing Firm

In the second stage, wholesale firm wants to maximize the real profits it gives back to households. Note that by (4.11) the number of working hours required for producing one unit of good is calculated as follows:

$$A_t K_t^{\alpha} L_t^{1-\alpha} = 1$$

$$A_t \left(\frac{\alpha\left(1 + k_Q I_t^{CB}\right) W_t L_t}{(1-\alpha) R_t^K} \right)^{\alpha} L_t^{1-\alpha} = 1$$

$$A_t \left(\frac{\alpha\left(1 + k_Q I_t^{CB}\right) W_t}{(1-\alpha) R_t^K} \right)^{\alpha} L_t = 1,$$

from which we get

$$L_t = \frac{1}{A_t} \left(\frac{\alpha\left(1 + k_Q I_t^{CB}\right) W_t}{(1-\alpha) R_t^K} \right)^{1-\alpha}.$$

The optimal cost of producing one unit of good $TC_t(1)$ can then be obtained by substituting the above quantity into (4.12) yielding

$$TC_t(1) = \frac{1}{A_t} \left(\frac{\left(1 + k_Q I_t^{CB}\right) W_t}{1-\alpha} \right)^{1-\alpha} \left(\frac{R_t^K}{\alpha} \right)^{\alpha}, \tag{4.16}$$

which is the same as (4.15). Expression (4.16), however, states that the marginal cost MC_t is nothing else than the optimal cost of producing one unit of good.

By this fact, the profit of wholesale firm j can be formulated as follows:

$$\Pi_{j,t}^{IF} = P_{j,t} Y_{j,t} - MC_t Y_{j,t}, \tag{4.17}$$

where the first term in the right-hand side of (4.17) is the total revenue and the second term is the total production cost. In addition to the stochastic discount factor β, wholesale firms will also discount future profits by ϕ. We also impose that the wholesale firms face the constraint that they can only adjust prices following a Calvo-type rule. The wholesale firm has a ϕ probability of keeping the price fixed in the next period and a $1-\phi$ probability of optimally determining its price. Hence (4.17) becomes

$$\Pi_{j,t}^{IF} = \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s (P_{j,t} Y_{j,t+s} - MC_{t+s} Y_{j,t+s}). \tag{4.18}$$

This profit function should be maximized subject to (4.3), which can be rewrite as

$$Y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\theta} Y_t. \tag{4.19}$$

Substitution constraint (4.19) into (4.18) gives

$$\Pi_{j,t}^{IF} = \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s (P_{j,t}^{1-\theta} P_{t+s}^{\theta} - P_{j,t}^{-\theta} P_{t+s}^{\theta} MC_{t+s}) Y_{t+s}, \tag{4.20}$$

and then the first order condition with respect to $P_{j,t}$ is

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s ((1-\theta) P_{j,t}^{-\theta} P_{t+s}^{\theta-1} + \theta P_{j,t}^{-\theta-1} P_{t+s}^{\theta-1} MC_{t+s}) Y_{t+s} = 0 \tag{4.21}$$

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \left(1 + \frac{\theta}{1-\theta} \frac{MC_{t+s}}{P_{j,t}}\right) = 0. \tag{4.22}$$

Thus, at time t wholesale firms choose $P_{j,t}$ so as to set a weighted average of the difference between marginal revenue and marginal cost to zero:

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$$\sum_{s=0}^{\infty}(\beta\phi)^s = \frac{\theta}{\theta-1}\mathbb{E}_t\sum_{s=0}^{\infty}(\beta\phi)^s\frac{MC_{t+s}}{P_{j,t}}$$

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3.1.2.5 Commercial Bank

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and then the first order condition with respect to $P_{j,t}$ is

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$$\sum_{s=0}^{\infty} (\beta\phi)^s = \frac{\theta}{\theta - 1} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s \frac{MC_{t+s}}{P_{j,t}}$$

$$\frac{P_{j,t}}{1-\beta\phi} = \frac{\theta}{\theta-1}\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s MC_{t+s}$$

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At this point, the so-called Calvo-Yun price setting was exploited by many literatures to linearize (4.22) around a deterministic steady state with zero-inflation leading to the famous linear New Keynesian Phillips curve involving inflation and marginal costs. See, for instance, Gali & Monacelli (2005) and Monacelli (2005). However, in this work, without restricting attention to the case of log-linear dynamics around a zero-inflation steady state, we follow an approach by Fernandez-Villaverde & Rubio-Ramírez (2006) and proceed (4.21) as follows:

$$\sum_{s=0}^{\infty} (\beta\phi)^s \left(\frac{1-\theta}{P_{j,t}} \left(\frac{P_{j,t}}{P_{t+s}} \right)^{1-\theta} + \frac{\theta}{P_{j,t}} \left(\frac{P_{j,t}}{P_{t+s}} \right)^{-\theta} \frac{MC_{t+s}}{P_{t+s}} \right) Y_{t+s} = 0$$

and then

$$\sum_{s=0}^{\infty} (\beta\phi)^s \left(\left(\frac{P_{j,t}}{P_{t+s}} \right)^{1-\theta} + \frac{\theta}{1-\theta} \left(\frac{P_{j,t}}{P_{t+s}} \right)^{-\theta} \frac{MC_{t+s}}{P_{t+s}} \right) Y_{t+s} = 0. \qquad (4.24)$$

As we will show later, log-linearization over (4.24) will provide relation between the price of final good P_t, the price of intermediate good $P_{j,t}$, the marginal cost MC_t, and inflation rate π_t.

3.1.2.6 Central Bank

The nominal interest rates on deposits I_t^D is given in (6.9) and that of government bonds I_t^B follows the interest rate on central bank funding I_t^{CB} in the way that

$$I_t^B = I_t^{CB} + \Delta_B, \qquad (7.1)$$

where $\Delta_B > 0$ is the fixed spread. The nominal interest rate on CBDC I_t^E is set by the central bank. In the case of non-bearing CBDC, the central bank sets $I_t^E = 0$. In order to utilize CBDC as a policy tool, for an interest-bearing CBDC, the interest rate on CBDC strictly follows the interest rate on central bank funding with an individual rule-based determination as suggested by Gross & Schiller (2021):

$$I_t^E = I_t^{CB} - \left(\Delta_E + k_N \frac{\bar{N} - N_t}{\bar{N}}\right). \tag{7.2}$$

The terms in brackets in (7.2) define the spread between the interest rates on central bank funding I_t^{CB} and that of CBDC I_t^E, where Δ_E is the fixed spread and N_t is the bank's equity with steady state value $\bar{N}$. The central bank may increase the spread based on financial stress after a shock, where parameter $k_N \in (0,1)$ denotes the reaction intensity and financial stress is expressed as the percentage deviation of banks' equity from steady state $(\bar{N} - N_t)/\bar{N}$.

The central bank sets the policy interest rate on central bank funding I_t^{CB} according to a Taylor-type rule. The policy rule is given in the following form:

$$I_t^{CB} = \rho_R I_t^{CB} + (1 - \rho_R)(\bar{R}^B + \Pi_t + \phi_\pi(\Pi_t - \Pi^T) + \phi_y(Y_t - \bar{Y}) + u_t, \tag{7.3}$$

where $\rho_R \in (0,1)$ is the interest rate smoothing parameter $\bar{R}^B$ is the steady state value of the bonds interest rate, Π_t is the current inflation rate, Π^T is the central bank's inflation target, Y_t is the output with steady state value $\bar{Y}$, ϕ_π and ϕ_y are respectively relative weights on inflation deviation and the output gap, and u_t is the monetary policy shock of AR(1) process:

$$u_t = \rho_u u_{t-1} + \varepsilon_t^u. \tag{7.4}$$

The central bank's assets consist of government bonds holding B_t^{CB}, tax payment TAX_t, and loans to the commercial bank Q_t^{CB}, whereas its liabilities comprise of total reserves TR_t and currency supplied to households and firms in the forms of cash M_t^S and CBDC E_t^S. The central bank's balance sheet is thus formulated as

$$(1 + I_t^B)B_t^{CB} + TAX_t + (1 + I_t^{CB})Q_t^{CB} = TR_t - TR_{t-1} + M_t^S + E_t^S. \quad (7.5)$$

Note that profits from bonds holding$I_t^B B_t^{CB}$ and from loan $I_t^{CB} Q_t^{CB}$ as well as lump sum tax TAX_t are then transferred to the government. Since the total reserves is a portion of total deposits and currencies supplies can be given by $M_t^S = M_t - \mu_m M_{t-1}$ and $E_t^S = E_t - \mu_e E_{t-1}$ for cash and CBDC, respectively, then (7.5) becomes

$$\begin{aligned}(1 + I_t^B)B_t^{CB} + TAX_t + (1 + I_t^{CB})Q_t^{CB} \\ = \psi(D_t - D_{t-1}) + (M_t - \mu_m M_{t-1}) + (E_t - \mu_e E_{t-1}),\end{aligned} \quad (7.6)$$

where μ_m and μ_e are the measure of nominal rigidity in the money supply process.

3.1.2.7 Government

In the economy, the government purchases the final good from retail firms G_t, collects taxes from households TAX_t, and issues one-period risk-free bonds B_t. The total bonds issued by government is held by commercial banks and the central bank such that

$$B_t = B_t^B + B_t^{CB}, \quad (8.1)$$

where B_t^B are bonds held by commercial bank and B_t^{CB} are those held by the central bank. Thus, the government's budget constraint is formulated as

$$P_t G_t + (1 + I_{t-1}^B)B_{t-1} = TAX_t + B_t + I_t^{CB} Q_t^{CB} + I_t^B B_t^{CB}, \quad (8.2)$$

where the last two terms in the right-hand side of (8.2) indicate respectively the profits earned by the central bank from loans and bonds holding which transferred to the government as fiscal authority. By (8.1) the budget constraint (8.2) becomes

$$P_t G_t + (1 + I_{t-1}^B)B_{t-1}^B + B_{t-1}^{CB} = TAX_t + B_t^B + I_t^{CB} Q_t^{CB} + (1 + I_t^B)B_t^{CB}. \quad (8.3)$$

We assume that the government's expenditure can be a constant fraction $k_G \in (0,1)$ of output of the final goods:

$$G_t = k_G Y_t. \tag{8.4}$$

Since output is divided into consumption, investment, and government spending, then the economy-wide budget constraint is expressed as

$$Y_t = C_t + INV_t + G_t. \tag{8.5}$$

3.1.3 Equilibrium and Steady State Conditions

In this section we summarize the equilibrium equations imposed by our model as results of optimization processes and identity relations. For each equilibrium equation, a steady state condition is given to be used in the log-linearization process.

1. Demand of CBDC:

$$\alpha_e \left(\frac{E_t}{P_t}\right)^{-\eta_e} = \frac{C_t^{-\sigma}}{P_t} - \beta(1 + I_t^E)\mathbb{E}_t \frac{C_{t+1}^{-\sigma}}{P_{t+1}},$$
$$\alpha_e \left(\frac{\bar{E}}{\bar{P}}\right)^{-\eta_e} = \frac{\bar{C}^{-\sigma}}{\bar{P}}\left(1 - \beta(1 + I_t^E)\right).$$

2. Demand of cash:

$$\alpha_m \left(\frac{M_t}{P_t}\right)^{-\eta_m} = \frac{C_t^{-\sigma}}{P_t} - \beta\mathbb{E}_t \frac{C_{t+1}^{-\sigma}}{P_{t+1}},$$
$$\alpha_m \left(\frac{\bar{M}}{\bar{P}}\right)^{-\eta_m} = \frac{\bar{C}^{-\sigma}}{\bar{P}}(1 - \beta).$$

3. Demand of bank deposits:

$$\alpha_d \left(\frac{D_t}{P_t}\right)^{-\eta_e} = \frac{C_t^{-\sigma}}{P_t} - \beta(1 + I_t^D)\mathbb{E}_t \frac{C_{t+1}^{-\sigma}}{P_{t+1}},$$
$$\alpha_d \left(\frac{\bar{D}}{\bar{P}}\right)^{-\eta_e} = \frac{\bar{C}^{-\sigma}}{\bar{P}}\left(1 - \beta(1 + I_t^D)\right).$$

4. The labor supply:

$$\alpha_l C_t^{\sigma} L_t^{\varphi} = \frac{W_t}{P_t},$$
$$\alpha_l \bar{C}^{\sigma} \bar{L}^{\varphi} = \frac{\bar{W}}{\bar{P}}.$$

5. Euler equation:

$$\left(\frac{\mathbb{E}_t C_{t+1}}{C_t}\right)^{\sigma} = \beta\left(1 - \delta + \mathbb{E}_t \frac{R_{t+1}^K}{P_{t+1}}\right),$$
$$1 = \beta\left(1 - \delta + \frac{\bar{R}^K}{\bar{P}}\right).$$

6. Capital stocks:

$$K_{t+1} = INV_t + (1 - \delta)K_t,$$
$$\overline{INV}_t = \delta \bar{K}.$$

7. Production function:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha},$$
$$\bar{Y} = \bar{A}\bar{K}^{\alpha}\bar{L}^{1-\alpha}.$$

8. Marginal cost:

$$MC_t = \frac{1}{A_t}\left(\frac{\left(1 + k_Q I_t^{CB}\right)W_t}{1 - \alpha}\right)^{1-\alpha}\left(\frac{R_t^K}{\alpha}\right)^{\alpha},$$
$$\overline{MC} = \frac{1}{\bar{A}}\left(\frac{\left(1 + k_Q \bar{I}^{CB}\right)\bar{W}}{1 - \alpha}\right)^{1-\alpha}\left(\frac{\bar{R}^K}{\alpha}\right)^{\alpha}.$$

9. Demand for labor:

$$L_t = (1-\alpha)\frac{MC_t}{1+k_Q I_t^{CB}}\frac{Y_t}{W_t},$$
$$\bar{L} = (1-\alpha)\frac{\overline{MC}}{1+k_Q \bar{I}^{CB}}\frac{\bar{Y}}{\bar{W}}.$$

10. Demand for capital:

$$K_t = \alpha MC_t \frac{Y_t}{R_t^K},$$
$$\bar{K} = \alpha \overline{MC}\frac{\bar{Y}}{\bar{R}^K}.$$

11. Price adjustment (Phillips curve):

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi)^s ((1-\theta)P_{j,t}^{-\theta} P_{t+s}^{\theta-1} + \theta P_{j,t}^{-\theta-1} P_{t+s}^{\theta-1} MC_{t+s}) Y_{t+s} = 0,$$
$$\bar{P} = \frac{\theta}{\theta-1}\overline{MC}.$$

12. Inflation rate:

$$\Pi_t = \frac{P_t}{P_{t-1}},$$
$$\bar{\Pi} = 1.$$

13. Optimal capital stock for capital producing firm:

$$\frac{C_t^{-\sigma}}{P_t}(1+I_t^L) = -\beta \mathbb{E}_t \frac{C_{t+1}^{-\sigma}}{P_{t+1}}\left(R_{t+1}^K + (1-\delta)(1+I_{t+1}^L)\right),$$
$$1+\bar{I}^L = -\beta\left(\bar{R}^K + (1-\delta)(1+\bar{I}^L)\right).$$

14. Bank's balance sheet:

$$k_Q W_t L_t + INV_t + B_t^B = Q_t^{CB} + (1-\psi)D_t + N_t,$$
$$k_Q \bar{W}\bar{L} + \overline{INV} + \bar{B}^B = \bar{Q}^{CB} + (1-\psi)\bar{D} + \bar{N}.$$

15. Bank's equity:

$$N_{t+1} = (1 + I_t^L)N_t + (I_t^L - I_t^D)D_t + (I_t^L - I_t^{CB})Q_t^{CB},$$
$$\bar{N} = (1 + \bar{I}^L)\bar{N} + (\bar{I}^L - \bar{I}^D)\bar{D} + (\bar{I}^L - \bar{I}^{CB})\bar{Q}^{CB}.$$

16. Loans interest rate:

$$1 + I_t^L = \frac{\phi_L(1 + I_t^{CB})INV_t}{N_t + (1 + \phi_L)INV_t},$$
$$1 + \bar{I}^L = \frac{\phi_L(1 + \bar{I}^{CB})\overline{INV}}{\bar{N} + (1 + \phi_L)\overline{INV}}.$$

17. Deposits interest rate:

$$1 + I_t^D = \frac{\phi_D(1 - \psi)}{1 + \phi_D}(1 + I_t^{CB}),$$
$$1 + \bar{I}^D = \frac{\phi_D(1 - \psi)}{1 + \phi_D}(1 + \bar{I}^{CB}).$$

18. Bonds interest rate:

$$I_t^B = I_t^{CB} + \Delta_B,$$
$$\bar{I}^B = \bar{I}^{CB} + \Delta_B.$$

19. CBDCs interest rate:

$$I_t^E = I_t^{CB} - \left(\Delta_E + k_N \frac{\bar{N} - N_t}{\bar{N}}\right),$$
$$\bar{I}^E = \bar{I}^{CB} - \Delta_E.$$

20. Taylor rule:

$$I_t^{CB} = \rho_R I_t^{CB} + (1 - \rho_R)(\bar{R}^B + \Pi_t + \phi_\pi(\Pi_t - \Pi^T) + \phi_y(Y_t - \bar{Y}) + u_t.$$

21. Central bank's balance sheet:

$$(1 + I_t^B)B_t^{CB} + TAX_t + (1 + I_t^{CB})Q_t^{CB} = \psi(D_t - D_{t-1}) + (M_t - \mu_m M_{t-1}) + (E_t - \mu_e E_{t-1}),$$
$$(1 + \bar{I}^B)\bar{B}^{CB} + \overline{TAX} + (1 + \bar{I}^{CB})\bar{Q}^{CB} = (1 - \mu_m)\bar{M} + (1 - \mu_e)\bar{E}.$$

22. Government's budget constraint:

$$P_t G_t + (1 + I_{t-1}^B)B_{t-1}^B + B_{t-1}^{CB} = TAX_t + B_t^B + I_t^{CB}Q_t^{CB} + (1 + I_t^B)B_t^{CB},$$
$$\bar{P}\bar{G} + \bar{I}^B\bar{B}^B = \overline{TAX} + \bar{I}^B\bar{B}^{CB} + \bar{I}^{CB}\bar{Q}^{CB}.$$

23. Government's spending:

$$G_t = k_G Y_t,$$
$$\bar{G} = k_G \bar{Y}.$$

24. Economy-wide budget constraint:

$$Y_t = C_t + INV_t + G_t,$$
$$\bar{Y} = \bar{C} + \overline{INV} + \bar{G}.$$

25. Productivity shock:

$$a_t = \rho_A a_{t-1} + \varepsilon_t^A.$$

26. Monetary policy shock:

$$u_t = \rho_u u_{t-1} + \varepsilon_t^u.$$

All steady state conditions must be simultaneously solved such that steady state values are obtained. With equation (4.2) it is not possible to know the value of productivity A_t at the steady state. The general price level is normalized, and the nominal interest rate of central bank is fixed. Then we initially assign the following steady state values:

$$\bar{A} = 1,$$

$$\bar{P} = 1,$$

$$\bar{I}^{CB} = 0.$$

We then obtain the rest of the steady state values:

$$\bar{R}^K = \left(\frac{1}{\beta} - 1 + \delta\right)\bar{P},$$

$$\overline{MC} = \frac{\theta - 1}{\theta}\bar{P},$$

$$\bar{I}^L = -\frac{\beta \bar{R}^K}{1 + \beta(1 - \delta)} - 1,$$

$$\bar{W} = \frac{1 - \alpha}{1 + k_Q \bar{I}^{CB}} (\overline{AMC})^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{\bar{R}^K}\right)^{\frac{\alpha}{1-\alpha}},$$

$$\bar{Y} = \left(\left(\frac{\bar{W}}{\alpha_l \bar{P}}\right)^{\frac{1}{\sigma}} \frac{\bar{R}^K}{(1 - k_G)\bar{R}^K - \alpha\delta\overline{MC}} \left(\frac{(1-\alpha)\overline{MC}}{\bar{W}}\right)^{-\frac{\varphi}{\sigma}}\right)^{\frac{\varphi}{\varphi - \sigma}},$$

$$\bar{K} = \alpha \overline{MC} \frac{\bar{Y}}{\bar{R}^K},$$

$$\overline{INV}_t = \delta \bar{K},$$

$$\bar{G} = k_G \bar{Y},$$

$$\bar{L} = (1 - \alpha) \frac{\overline{MC}}{1 + k_Q \bar{I}^{CB}} \frac{\bar{Y}}{\bar{W}},$$

$$\bar{C} = \bar{Y} - \overline{INV} - \bar{G},$$

$$\bar{M} = \bar{P} \left(\frac{\bar{C}^{-\sigma}}{\alpha_m \bar{P}} (1 - \beta)\right)^{-\frac{1}{\eta_m}},$$

$$\bar{I}^D = \frac{\phi_D (1 - \psi)}{1 + \phi_D} (1 + \bar{I}^{CB}) - 1,$$

$$\bar{I}^B = \bar{I}^{CB} + \Delta_B,$$

$$\bar{I}^E = \bar{I}^{CB} - \Delta_E,$$

$$\bar{E} = \bar{P}\left(\frac{\bar{C}^{-\sigma}}{\alpha_e \bar{P}}(1-\beta(1+\bar{I}^E))\right)^{-\frac{1}{\eta_e}},$$

$$\bar{D} = \bar{P}\left(\frac{\bar{C}^{-\sigma}}{\alpha_d \bar{P}}(1-\beta(1+\bar{I}^D))\right)^{-\frac{1}{\eta_d}},$$

$$\bar{N} = \frac{\phi_L(1+\bar{I}^{CB})\overline{INV}}{1+\bar{I}^L} - (1+\phi_L)\overline{INV},$$

$$\bar{Q}^{CB} = \frac{\bar{I}^L\bar{N} + (\bar{I}^L - \bar{I}^D)\bar{D}}{\bar{I}^{CB} - \bar{I}^L},$$

$$\bar{B}^B = \bar{Q}^{CB} + (1-\psi)\bar{D} + \bar{N} - k_Q\bar{W}\bar{L} - \overline{INV},$$

$$\bar{B}^{CB} = (1-\mu_m)\bar{M} + (1-\mu_e)\bar{E} - \bar{Q}^{CB} - \bar{P}\bar{G} - \bar{I}^B\bar{B}^B,$$

$$\overline{TAX} = \bar{P}\bar{G} + \bar{I}^B\bar{B}^B - \bar{I}^{CB}\bar{Q}^{CB} - \bar{I}^B\bar{B}^{CB}.$$

3.1.4 Log-linearization

One easy and common approach to solve and analyze DSGE models is to approximate the nonlinear equations characterizing the equilibrium with the corresponding log-linearized equations. The principle is to employ a first order Taylor approximation around a particular point (usually a steady state value) to replace the nonlinear equations with their approximations, which are linear in the log-deviations of the variables. In this work we follow a log-linearization method proposed by Uhlig (1999).

3.1.4.1 Uhlig's Method

Let X_t is the value of variable at time t and $\bar{X}$ is the steady state value of X_t. The log-linearized value of X_t, denoted by x_t, is defined as

$$x_t = \ln X_t - \ln \bar{X} = \ln \frac{X_t}{\bar{X}}. \tag{9.1}$$

Since the first order Taylor approximation of function $h = h(x)$ around $x = a$ is given by

$$h(x) \approx h(a) + h'(a)(x - a) \tag{9.2}$$

and thus for $h(X_t) = \ln X_t/\bar{X}$ we have $h'(x) = 1/X_t$, and then X_t can be approximated by x_t around its steady state value $\bar{X}$ according to (9.1) and (9.2):

$$x_t \approx \frac{X_t - \bar{X}}{\bar{X}},$$

from which we obtain the equivalency

$$X_t \approx \bar{X}(1 + x_t). \tag{9.3}$$

By (9.3), $100x_t$ informs us by how much, in per cent, the variable X_t differs from its steady state level $\bar{X}$ in period t. Alternatively by taking the exponent of both sides of (9.1) we obtain

$$X_t \approx \bar{X}e^{x_t}. \tag{9.4}$$

By fact that Taylor approximation provides $e^{x_t} \approx 1 + x_t$, then we again reclaim (9.3) from (9.4). Thus, log-linearization of X_t can be undertaken by replacing it with either $\bar{X}e^{x_t}$ or $\bar{X}(1 + x_t)$.

3.1.5 Log-linearized Equations

The followings are the log-linearized version of all equilibrium conditions obtained by using Uhlig's method.

1. Demand of CBDC:

$$\alpha_e \left(\frac{\bar{E}}{\bar{P}}\right)^{-\eta_e} \eta_e(p_t - e_t) = -\frac{\bar{C}^{-\sigma}}{\bar{P}}(\sigma c_t + p_t) + \beta \frac{\bar{C}^{-\sigma}(1 + \bar{I}^E)}{\bar{P}} \mathbb{E}_t \left(\sigma c_{t+1} - \frac{\bar{I}^E}{1 + \bar{I}^E} i_t^E + p_{t+1}\right).$$

2. Demand of cash:

$$\alpha_m \left(\frac{\bar{M}}{\bar{P}}\right)^{-\eta_m} \eta_m(p_t - m_t) = -\frac{\bar{C}^{-\sigma}}{\bar{P}}(\sigma c_t + p_t) + \beta \frac{\bar{C}^{-\sigma}}{\bar{P}} \mathbb{E}_t(\sigma c_{t+1} + p_{t+1}).$$

3. Demand of bank deposits:

$$\alpha_d \left(\frac{\bar{D}}{\bar{P}}\right)^{-\eta_d} \eta_d (p_t - d_t) = -\frac{\bar{C}^{-\sigma}}{\bar{P}}(\sigma c_t + p_t) + \beta \frac{\bar{C}^{-\sigma}(1+\bar{I}^D)}{\bar{P}} \mathbb{E}_t \left(\sigma c_{t+1} - \frac{\bar{I}^D}{1+\bar{I}^D} i_t^D + p_{t+1}\right).$$

4. The labor supply:

$$\sigma c_t + \varphi l_t = w_t - p_t.$$

5. Euler equation:

$$\sigma \bar{P} \mathbb{E}_t (c_{t+1} - c_t) = \beta \bar{R}^K \mathbb{E}_t (r_{t+1}^K - p_{t+1}).$$

6. Capital stocks:

$$k_{t+1} = \delta inv_t + (1-\delta) k_t.$$

7. Production function:

$$y_t = a_t + \alpha k_t + (1-\alpha) l_t.$$

8. Marginal cost:

$$mc_t = -a_t + (1-\alpha)\left(\frac{k_Q \bar{I}^{CB}}{1 + k_Q \bar{I}^{CB}} i_t^{CB} + w_t\right) + \alpha r_t^K.$$

9. Demand for labor:

$$l_t = mc_t + y_t - \frac{k_Q \bar{I}^{CB}}{1 + k_Q \bar{I}^{CB}} i_t^{CB} - w_t.$$

10. Demand for capital:

$$k_t = mc_t + y_t - r_t^K.$$

11. Price adjustment (Phillips curve):

$$\pi_t = \frac{(1-\beta\phi)(1-\phi)}{\phi}(mc_t - p_t) + \beta \mathbb{E}_t \pi_{t+1}.$$

12. Inflation rate:

$$\pi_t = p_t - p_{t-1}.$$

13. Optimal capital stock for capital producing firm:

$$\bar{I}^L i_t^L - (1+\bar{I}^L)(\sigma c_t + p_t) = \beta(1+\bar{R}^K)(1-\delta)(1+\bar{I}^L)\mathbb{E}_t(\sigma c_{t+1} + p_{t+1}) - \beta \mathbb{E}_t(\bar{R}^K r_{t+1}^K + (1-\delta)\bar{I}^L i_{t+1}^L.$$

14. Bank's balance sheet:

$$k_Q \bar{W} \bar{L}(w_t + l_t) + \overline{INV} inv_t + \bar{B}^B b_t^B = \bar{Q}^{CB} q_t^{CB} + (1 - \psi)\bar{D} d_t + \bar{N} n_t.$$

15. Bank's equity:

$$\begin{aligned}\bar{N}(n_{t+1} - n_t) = {} & \bar{I}^L \bar{N}(i_t^L + n_t) + \bar{I}^L \bar{D}(i_t^L + d_t) - \bar{I}^D \bar{D}(i_t^D + d_t) + \bar{I}^L \bar{Q}^{CB}(i_t^L + q_t^{CB}) \\ & - \bar{I}^{CB} \bar{Q}^{CB}(i_t^{CB} + q_t^{CB})\end{aligned}$$

16. Loans interest rate:

$$\begin{aligned}\bar{N} n_t + (1 + \phi_L)\overline{INV} inv_t + \bar{N} \bar{I}^L (n_t + i_t^L) + (1 + \phi_L)\overline{INV} \bar{I}^L (inv_t + i_t^L) \\ = \phi_L \overline{INV} inv_t + \phi_L \bar{I}^{CB} \overline{INV}(i_t^{CB} + inv_t).\end{aligned}$$

17. Deposits interest rate:

$$\bar{I}^D i_t^D = \frac{\phi_D (1 - \psi)\bar{I}^{CB}}{1 + \phi_D} i_t^{CB}.$$

18. Bonds interest rate:

$$i_t^B = i_t^{CB} + \Delta_B.$$

19. CBDCs interest rate:

$$i_t^E = i_t^{CB} - \left(\Delta_E + k_N \frac{\bar{N} - n_t}{\bar{N}}\right).$$

20. Taylor rule:

$$i_t^{CB} = \rho_R i_t^{CB} + (1 - \rho_R)(\bar{R}^B + \pi_t + \phi_\pi(\pi_t - \Pi^T) + \phi_y(y_t - \bar{Y}) + u_t.$$

21. Central bank's balance sheet:

$$\begin{aligned}\bar{B}^{CB} b_t^{CB} + \bar{I}^B \bar{B}^{CB}(i_t^B + b_t^{CB}) + \overline{TAX} tax_t + \bar{Q}^{CB} q_t^{CB} + \bar{I}^{CB} \bar{Q}^{CB}(i_t^{CB} + q_t^{CB}) \\ = \psi \bar{D}(d_t - d_{t-1}) + \bar{M}(m_t - \mu_m m_{t-1}) + \bar{E}(e_t - \mu_e e_{t-1}).\end{aligned}$$

22. Government's budget constraint:

$$\begin{aligned}\bar{P}\bar{G}(p_t + g_t) + \bar{B}^B b_{t-1}^B + \bar{I}^B \bar{B}^B (i_{t-1}^B + b_{t-1}^B) + \bar{B}^{CB} b_{t-1}^{CB} \\ = \overline{TAX} tax_t + \bar{B}^B b_t^B + \bar{B}^{CB} b_t^{CB} + \bar{I}^B \bar{B}^{CB}(i_t^B + b_t^{CB}) + \bar{I}^{CB} \bar{Q}^{CB}(i_t^{CB} + q_t^{CB}).\end{aligned}$$

23. Government's spending:

$$\bar{G} g_t = k_G \bar{Y} y_t.$$

24. Economy-wide budget constraint:

$$\bar{Y} y_t = \bar{C} c_t + \overline{INV} inv_t + \bar{G} g_t.$$

25. Productivity shock:

$$a_t = \rho_A a_{t-1} + \varepsilon_t^A.$$

26. Monetary policy shock:

$$u_t = \rho_u u_{t-1} + \varepsilon_t^u.$$

and therefore

$$\begin{aligned} & \bar{P}\bar{G}(p_t + g_t) + \bar{B}^B b_{t-1}^B + \bar{I}^B \bar{B}^B (i_{t-1}^B + b_{t-1}^B) + \bar{B}^{CB} b_{t-1}^{CB} \\ = \; & \overline{TAX} tax_t + \bar{B}^B b_t^B + \bar{B}^{CB} b_t^{CB} + \bar{I}^B \bar{B}^{CB} (i_t^B + b_t^{CB}) + \bar{I}^{CB} \bar{Q}^{CB} (i_t^{CB} + q_t^{CB}). \quad (163) \end{aligned}$$

3.1.6 Shock Generators

3.1.6.1 Productivity Shock

The production function of wholesale goods follows the Cobb Douglas and given in (43)

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

Where A_t is the productivity or technology shock. This shock is governed by the first order autoregressive process

$$ln\, A_t = \rho_A ln\, A_{t-1} + \varepsilon_t,$$

Which can be expressed in log-linearized form as

$$\alpha_t = \rho_A \alpha_{t-1} + \varepsilon_t$$

The productivity shock will affect the marginal cost of production, i.e., the optimal cost of producing one unit of goods. The log-linearized version of the marginal cost is provided in (133)

$$mc_t = -\alpha_t + (1-\alpha)\left(\frac{k_Q \bar{R}^L}{1 + k_Q \bar{R}^L} r_t^L + \omega_t\right) + \alpha r_t^K$$

3.1.6.2 Interest Rate Shock

The policy of interest rate on the central bank funding follows the Taylor-type rule:

$$\bar{R}^{CB} r_t^{CB} = \rho R^{\bar{R}^{CB}} r_{t-1}^{CB} + (1-\rho_R)\left((1+\rho_\pi)\pi^T \pi_t + \rho_y y_t\right) + s_t^R,$$

where s_t^R is the shock given by

$$S_t^R = \phi R^{s_{t-1}^R} - \varepsilon_t$$

3.2 SWOT Approach

3.2.1 Data

This research wants to examines the optimal CBDC design using SWOT analysis. A purposive sampling of literatures is used to extract various literature of CBDC development across the world including motivation, design characteristic, macroeconomic implication, and lesson learned. Article journal is taken from the one that indexed in Scopus. Working papers only be extracted from credible institutions such as BIS, CEMLA, ADB, ECB, World Bank, FSB, PwC, Deloitte, and EY. Some webinars that the speakers originated from BIS. News platform that will be used is Wall Street Journal and Central Banking. The country use case that used in this research is China, Canada, Sweden, Bahamas, USA, Swiss, France, Canada, Eastern Caribbean, Singapore, Thailand, Hong Kong, Japan, Uruguay, Denmark, Ecuador, Poland, England, Japan, Nigeria, Jamaica, Ghana, and Russia. The set of selected countries is considered based on the

availability of the CBDC development progress in research, proof-of-concept, pilot, or live implementation.

3.2.2 Methods

The method used to determine the CBDC design in this research is the SWOT analysis. This analysis is commonly used to manage information by dividing it into (S) Strengths, (W) Weaknesses, (O) Opportunities, and (T) Threats. Gurel & Tat (2017) explained that strengths are the aspects that add value to something and makes it more special than others, weaknesses are the aspects of not having or weaker competency compared to others, opportunities are the aspects of condition or situation that are suitable for us, and threats are the aspects that become an obstacle that makes us harder to reach our goal[20]. That information is used for analysis in developing strategies by optimizing Strengths and Opportunities while removing Weaknesses and Treats (Kowalska-Pyzalska et al., 2020). This analysis is not limited to business models but can be used for decisions making in the policy. For example, this analysis was also conducted for the impact of the decline in world oil prices (Q. Wang & Li, 2016), construction project planning (Lu, 2010), organic waste in the circular economy (Paes et al., 2019), and the Corn Industry in Heilongjiang Province (Wan-rong et al., 2013). These examples show that SWOT analysis can accommodate analysis in the application of CBDC so that we can find the most appropriate design of CBDC and know the impact of macroeconomic policies.

	Positive aspects	Negative aspects
Internal aspects	**Strengths:** The aspects that add value to something and makes it more special than others	**Weaknesses:** The aspects of not having or weaker competency compared to others
External aspects	**Opportunities:** The aspects of condition or situation that suitable for us	**Threats:** The aspects that become an obstacle that makes us harder to reach our goal

Table 1 SWOT Analysis

Source: Adapted from Gurel & Tat (2017)

[20] In this research, the "others" term that used as a comparation with CBDC is cash.

However, SWOT itself has the disadvantages of inability to identify the SWOT aspects priorities (Gurel & Tat, 2017). It is not clear which SWOT characteristics how much impact that could be inflicted by its SWOT aspects. Therefore, this research uses meta-analysis as an additional tool for the SWOT analysis. Meta-analysis is the integration of the quantitative methods by consolidating other research findings (Borenstein et al., 2009). This analysis could find the effect size from each SWOT aspects and solve the previous disadvantages of SWOT analysis. For the effect size calculation, this research will adapt from Agarwal et al. (2012) due to the utilization of Meta-SWOT in their research. SWOT on both CBDC will be elaborated first. After that, each characteristic will receive a point based on the compatibility against the SWOT and its competitiveness against other characteristics. Below is the point that will be used for basis:

	Internal Factors		External Factors	
	Strengths	Weaknesses	Opportunities	Threats
Yes	+1	-1	+1	-1
Quasi Yes	+0.75	-0.75	+0.75	-0.75
Depend	+0.5	-0.5	+0.5	-0.5
Quasi No	+0.25	-0.25	+0.25	-0.25
No	0	0	0	0

Table 2 Scores of SWOT Analysis

Source: Adapted from Agarwal et al. (2012)

When the CBDC characteristics carry absolute attributes that do not rely on other characteristics, it will be considered "Yes". The "Quasi Yes" will be achieved when that characteristic has the attributes, but it still loses to the other characteristics in the same classification. The "Depend" will be achieved if the characteristics rely on the other classification. The "Quasi no" will be given when the characteristic has weak attributes on it. Lastly, "No" attributes will be given if the characteristic does not carry any of that attribute.

	CLASSIFICATIONS

		A		B		C		D		E			F		G	
		CHARACTERISTICS														
		1	2	1	2	1	2	1	2	1	2	3	1	2	1	2
ASPECTS	**Strengths**															
	S1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	S2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	S3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	S4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Weaknesses															
	W1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	W2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	W3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	W4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Opportunities															
	O1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	O2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	O3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	O4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Threats															
	T1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	T2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	T3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	T4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum
	S1-S4: Strength aspect W1-W4: Weaknesses aspect O1-O4: Opportunities aspect T1-T2: Threats aspect A-G: Classifications 1-3: Characteristics x: Score															

Table 3 General SWOT Matrix

Source: Constructed by author

To become a concrete strategy, we will optimize strengths with existing opportunities. Strengths can also be used to minimize potential threats that arise. Weaknesses can also be minimized by utilizing opportunities optimally. Then, we must also make efforts to cover our weaknesses to avoid potential threats that arise

	SWOT Strategies	
	Strength aspects	Weakness aspects
Opportunity aspects	S-O Strategies: Using internal strength and utilize available opportunities	W-O Strategies: Utilizing opportunities to mitigate internal weaknesses

Threat aspects	S-T Strategies: Utilizing internal strengths to mitigate revealed threats	W-T Strategies: Mitigating internal weaknesses so we could avoid the incoming threat

Table 4 SWOT Strategies

Source: Adapted from Chermack & Kasshanna (2017)

The characteristics that achieve the most points will be considered as the beneficial design. But that beneficial design is not yet considered as the most optimal CBDC design. Therefore, it needs to be adjusted again with its country needs and capabilities in the next phase.

4. Result and Discussion

4.1 Result and Discussion of Macroeconomic Consequences and Monetary Policy Implication

4.1.1 Simulations Result

4.1.1.1 Productivity Shock

The results of a positive productivity shock on variables of the model are presented here. The productivity shock due to the technological advance causes a rise in the values of the marginal products of labor and capital, and thus firms increase their demand for labor and capital as production inputs, so investment level increased. Increasing productivity implies that firms operate more efficiently so the marginal costs decrease. Meanwhile, inflations fall as the production becomes more efficient and increases the supply of goods, thus leading to easing in monetary policy followed by reduced CBDC dan banks rate. Due to the inverted relationship between bond and interest rate, the reduction of the interest rate makes the bond price raising, thus both central bank and banks reduce their bond holding. Increased productivity also implies raising the wage and capital return which makes the laborers tend to use their leisure time for consumption, thus reducing their working hours. Wage and capital return raise also implies that households tend to consume rather than save, thus decreasing holding of cash, CBDC, and deposit. Both activities from households and firms are contributing to the tax revenue, thus increasing government spending. All of those results imply the increase in aggregate demand, then increasing the output.

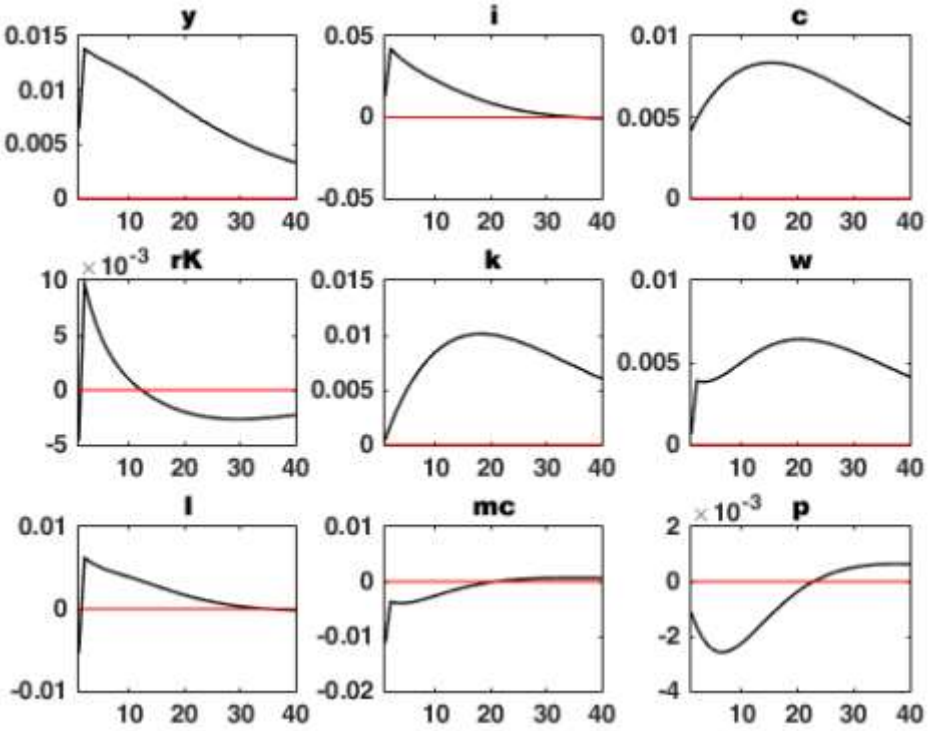

Figure 4.1 IRF of Effects on Productivity Shock (1)

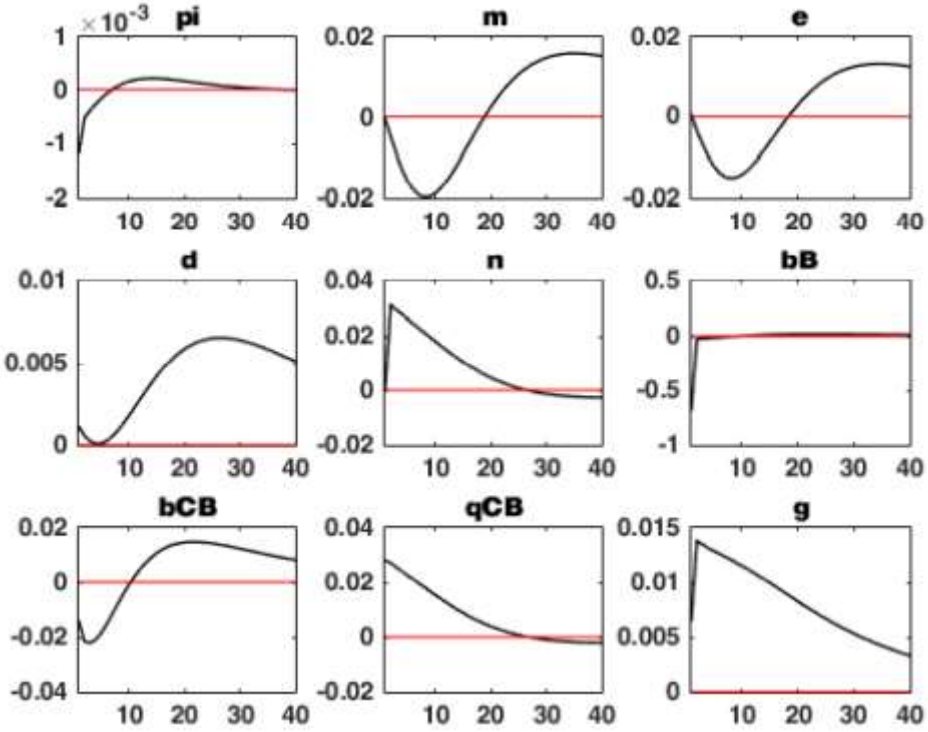

Figure 4.2 IRF of Effects on Productivity Shock (2)

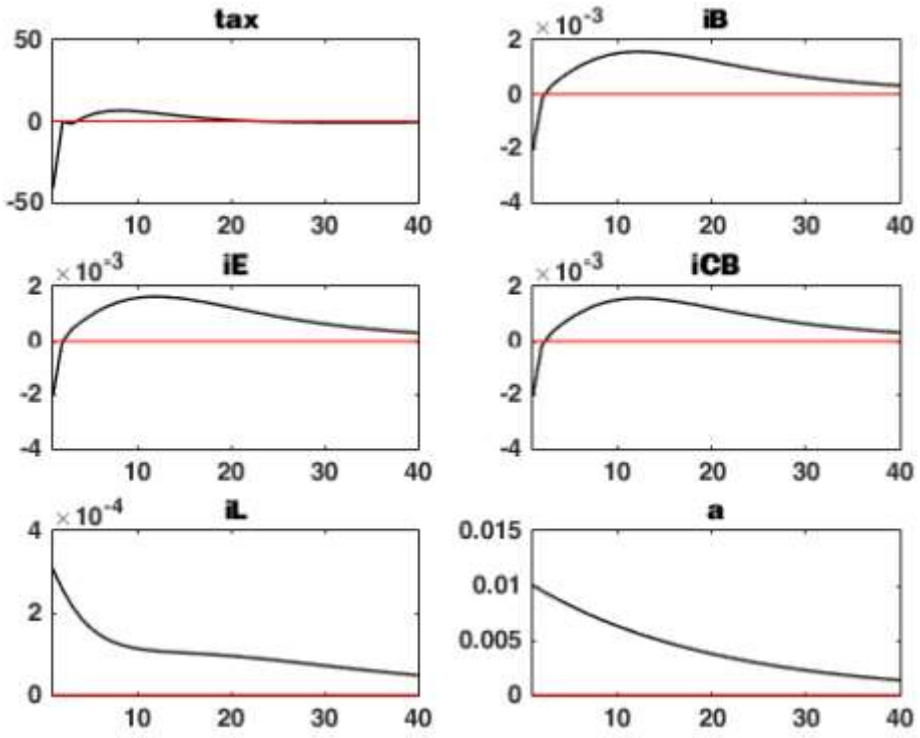

Figure 4.3 IRF of Effects on Productivity Shock (3)

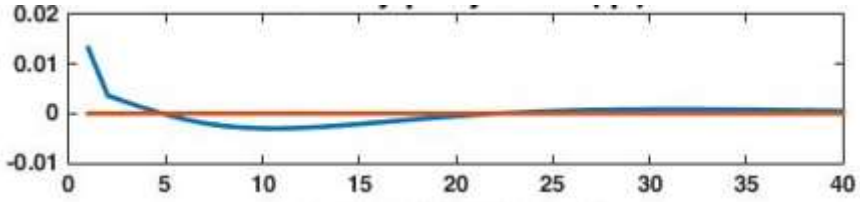

Figure 4.4 IRF Effect on Productivity Shock of Bank Loan

However, due to the increased aggregate demand, the price level also increased and raised the inflation rate. The sign of inflation makes the central bank take an action. The central bank responds with an increment of its policy rate followed by CBDC and banks rate to make an economic contraction by reducing purchasing power. As the consequence, bank capital is decreasing due to the decreasing loans and increased liability due to the raising deposit rate. An increment of policy rate also implies the reduction of bond price, thus central banks and banks buy more bonds. As the result, the rising interest rate makes consumption and investment decline. Both people and firms tend to save their money in CBDC rather than the deposit due to the CBDC attributes of being a risk-free asset. Decreasing consumption implies reduced firm productivity, thus reducing the wage of the labor, moreover, the technology starting to deteriorate as the technology keeps depreciating. As the sources of tax revenue decreased, government spending also decreased. In the end, the aggregate demand will be reduced, thus the output is also declining.

This result aligned with Ammu George et al. (2021) and Lim et al. (2021). Both of the results imply that CBDC would likely make monetary policy more effective. It can be seen by the response of the central bank towards inflation using CBDC rate is effective. Moreover, households show that remunerated CBDC is more attractive than bonds to fulfill their liquidity, so it enhances the monetary policy effectiveness

4.1.1.2 Policy Interest Rate Shock

The results of an increasing policy interest rate shock on variables of the model are presented here. Initially, Increasing policy rate is followed by the increment of CBDC rate .However, there is lag in monetary policy transmission due to the cost adjustment of investment gradual response as mentioned by Gruend et al., (1997). In this lag period, household and firm tends to borrow money from bank to consume and invest before the bank done adjusting the interest rate, respectively. This lag explains why initially there is a short span increment in output when there is increment in the policy rate. After that period, household tends to substitute deposit to cash and CBDC due to the consideration of risk-free assets. CBDC also become an alternative to fulfil liquidity demand. Holding CBDC will increase the household's overall liquidity, even though liquidity marginal utility decreased. Therefore, it's more explaining why CBDC is more attractive than the deposit. Since CBDC is remunerated, the households tend to convert more CBDC rather than cash. The reduction of the deposit implies that banks have reduced credit supply, thus decreasing their lending power. As the result, there is a decrease in investment which implies reduced labor as well as wages. Households also tend to save rather than take a loan. Reduced household and firm activity imply a reduction in purchasing power, thus reducing consumption as well as tax revenue. Due to the reduction in tax revenue, the government is also reducing its government spending. Reduced consumption and government spending also imply there is an excess supply of goods, which reduces the price level and inflation rate. Therefore, the reduction of aggregate demand reflects the reduction of output.

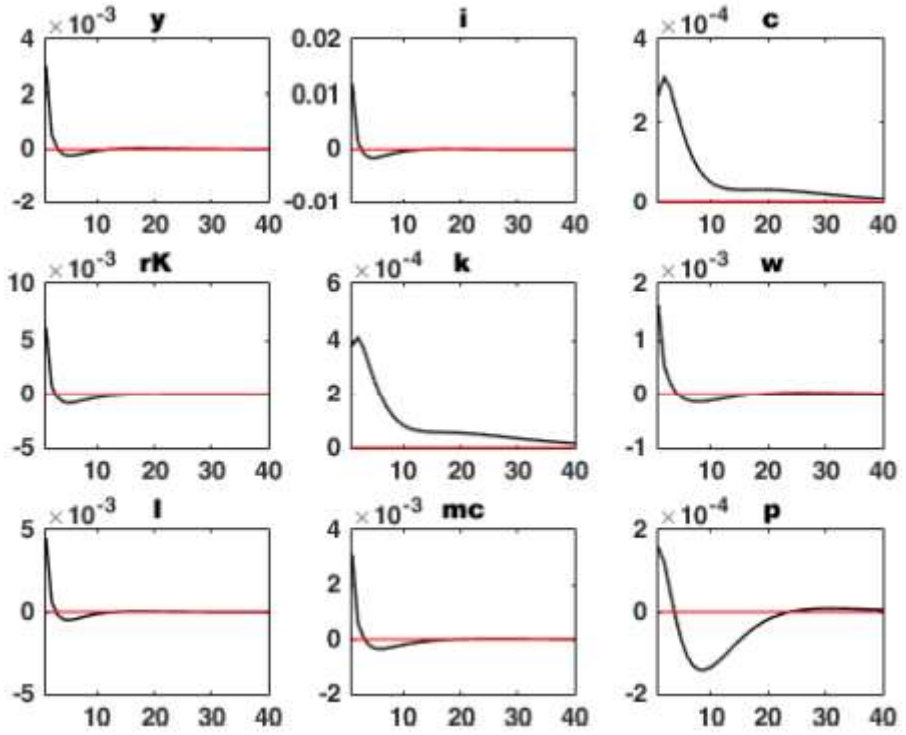

Figure 4.5 IRF Effects on Monetary Policy Shock (1)

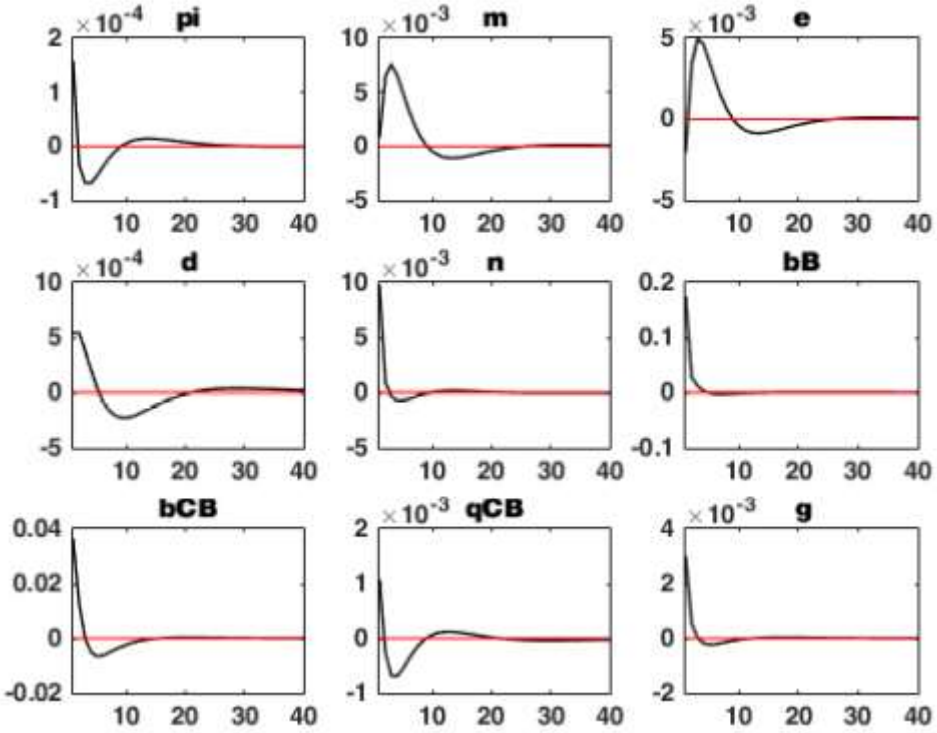

Figure 4.6 IRF Effects on Monetary Policy Shock (2)

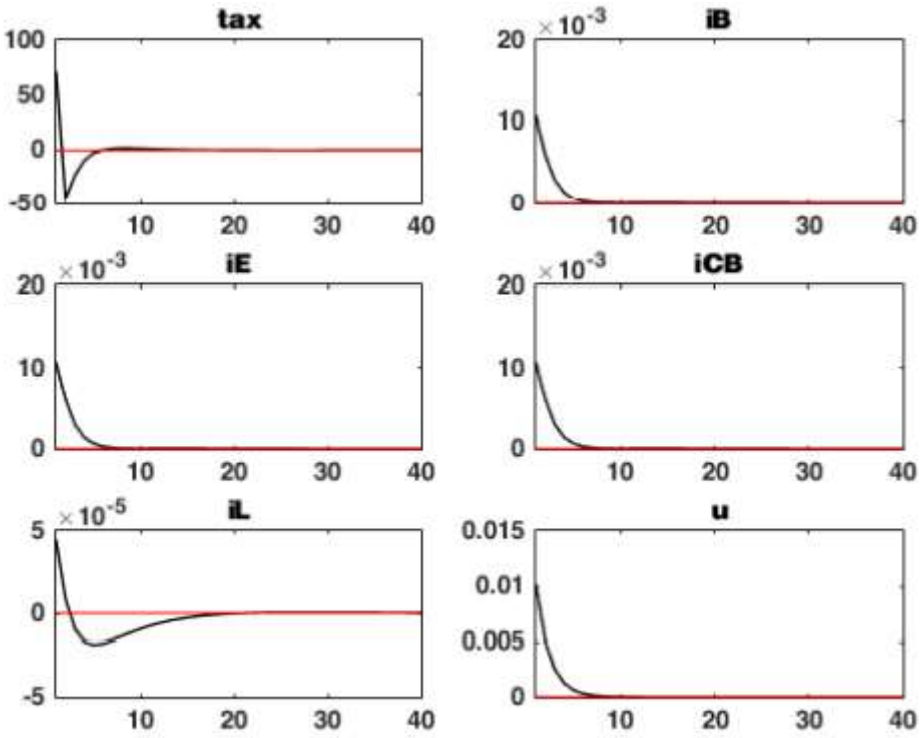

Figure 4.7 IRF Effects on Monetary Policy Shock (3)

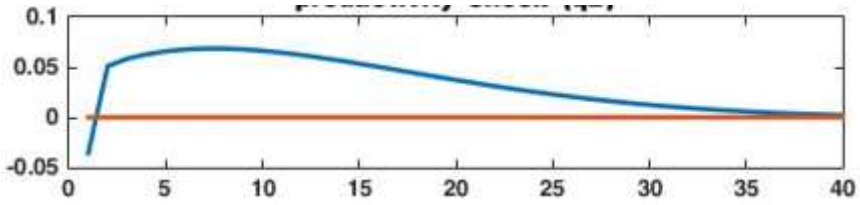

Figure 4.8 IRF Effects on Monetary Policy Shock of Bank Loan

However, as the economy started to the downturn, the central banks respond to it with expansionary policy. The economic recovery was followed by a reduction of the CBDC and banks rate. This drive household and firm to consume and invest, respectively. Household and firm spend their money, thus CBDC and cash holding decrease. Households tend to consume more and firms tend to expand their business as can be seen from the increment in capital, labor, and wage. Both consumption and investment contribute to the aggregate demand, thus increasing the price level and inflation rate. As the economic activity got warmed up, the tax revenue also increased, thus increasing the government spending. In the end, the output will increase as the economic activity recovers.

The result of this simulation also aligned with Gross & Schiller (2021). It is emphasizing that CBDC is a feasible alternative means of payment in times of financial

stress. Therefore, using CBDC would likely make monetary policy more effective, moreover if it remunerated. The central bank could directly govern the CBDC rate through the wallet or implementing CBDC capacity.

4.2 Result and Discussion of Optimal CBDC Design

4.2.1 SWOT Analysis – Strength Aspect

4.2.1.1 Payment Efficiency

Practically, payment efficiency would be promoted by the CBDC development (Bordo & Levin, 2017). He et al. (2014) argue that CBDC enables us to accommodate rapid and secure cross-border settlement. The settlement could become near-instant because it is possible to be conducted on a peer-to-peer basis, and available 24/7 (CPMI, 2018a; PwC, 2019). Cross-border would be faster, cheaper, transparent, and inclusive, thus giving benefits for worldwide economics (BIS et al., 2021). When compared to cash, CBDC would likely reduce the cost of handling and lower transaction fees, which is beneficial for households and businesses[21] (Bordo & Levin, 2017; Raghuveera & Bray, 2020). From a macroeconomics perspective, CBDC also gives efficiency because productivity gains from CBDC implementation would be identical to the reduction of substantial distortionary taxes (Barrdear & Kumhof, 2017). CBDC payment efficiency also could reduce the number of policy transmissions, thus increasing the effectiveness of monetary policy (Luo et al., 2021).

Current CBDC development shows us that CBDC promotes payment efficiency. Southern Caribbean was able to eliminate transfer fees to promote cost efficiency in their CBDC (Eastern Caribbean Central Bank, n.d.-c). Sweden develops CBDC to cater phenomenon of declining cash usage. It's not efficient to use cash in Sweden because, in 2018, the usage of paper money is only 10 percent (Riksbank, 2020). Sweden developing CBDC to support public awareness and encourage payment efficiency (Boar & Wehrli, 2021). Hong Kong-Thailand, Singapore-Canada, Europe-Japan, United Arab Emirates-Saudi Arabia, and several other countries are testing the potential efficiency of cross-border payments, all of these tests are still in the pilot phase (Kalfon et al., 2021).

21 Cost of cash handling is estimated 0.5 percent of Europe Union GDP, which mean its save a lot from high cost that associated with cash (Gnan & Masciandaro, 2018)

The outcome of those pilot testing gives the varying form of payment efficiencies such as real-time settlement, costless transaction, and resilience financial stability.

4.2.1.2 Monetary Policy Effectiveness

Monetary policy can be more effective through CBDC because of the faster transmission (Agur et al., 2018). Also, monetary policy could be implemented by adjusting the CBDC rate directly through their wallet rather than influencing commercial banks through policy rates (Mookerjee, 2021; Nelson, 2021). Aside from transmission, CBDC enables the central bank to extract real-time data, which increases the response time of the central bank in monetary policy implementation (Burgos & Batavia, 2018). Some monetary policies will be more effective if we implement CBDC. Assuming cash is absent, CBDC able to penetrate the Zero Lower Bound and able to provide a stimulus to public consumption in the event of an economic downturn (Davoodalhosseini et al., 2020). Helicopter money also will be more effective because CBDC enable us to transfer money such as aid, directly to people with less bureaucracy (BIS, 2020). However, gradual response of investment still could gives a lag to monetary policy transmission due to the cost adjustment (Gruend et al., 1997).

There are some use cases from either research or pilot testing of CBDC that influence monetary policy. In their pilot, ECB plans to impose a balance limit and set the CBDC rate that is less than safe assets like a deposit to prevent the deposit crowding out (Goldman Sachs Global Investment Research, 2020). Nigeria also wants to extend potential CBDC benefits for monetary policy effectiveness in their pilot (Huillet, 2021). Research by Janet Jiang & Zhu (2021) concludes that the CBDC rate has a strong monetary policy pass-through to the loan market if the coordination of policy rates is effective. Meanwhile, Sweden with their e-krona still evaluate the interest-bearing for consideration of lower bound constraint (IMF, 2021a)

4.2.1.3 Increasing Financial Inclusion

Financial inclusion means that individuals and businesses have access to useful and affordable financial products and services that meet their needs – transactions, payments, savings, credit and insurance – delivered in a responsible and sustainable way (World Bank, 2018). Financial inclusion is one of the important concerns that push the CBDC development (Kiff et al., 2020b). CBDC can boost financial inclusion by transforming the unbanked community into integrated with the bank system, thus they can harness financial services such as payments, transfers, savings, credit, insurance, and so on (Wallis,

2021). Also, CBDC is considered a risk-free asset and makes people willing to convert to CBDC (Mersch, 2020). Promoting financial inclusion will support direct aid from the government, prevent fraud (AML, CFT, Tax evasion), digitalization of value chain, reduce cash management costs, and increase monetary policy effectiveness (Didenko & Buckley, 2021; Lapukeni, 2015). These benefits will give the central bank more sovereignty over the circulation of digitalized money.

Some CBDC development shows us the financial inclusion that is given by CBDC. China uses NFC to encourage financial inclusion, especially in their large and remote areas (Chow & Eckert, 2021). Using NFC also means the transaction can be conducted by placing the device side by side, which means without an internet connection. The Bahamas' Sand Dollar also allows CBDC to be used in areas without internet and can operate 24/7 (Bharathan, 2020). This will support the Bahamas to push financial inclusion within its archipelago in more than 700 islands (Turner, 2020). Bahamas neighborhood, East Caribbean, also developing CBDC in the form of a value-based wallet that is easy to be integrated without a bank account and low transaction cost, thus lowering the barrier-to-entry (Eastern Caribbean Central Bank, n.d.-b). That benefit is compelling for the countries that have a geographical limitation like archipelago countries. China also has similar methods to overcome unbanked people by providing safe and liquid payment to the public without requiring bank account (Goldman Sachs Global Investment Research, 2020).. Due to low transaction cost, low-income people would likely to easily convert from unbanked to banked (Caskey, 2002).

4.2.1.4 Traceability

Currently, data is the most valuable resource than oil, data can bring new insights that contribute the innovation, which also able to trace our daily activities (Bhagesphur, 2019). Traceable CBDC allows us to get better real-time data through data from each transaction (CPMI, 2018a; Mookerjee, 2021). With IoT, we can import data from CBDC and use it to monitor economic activities by recording each transaction, thus we could able to calculate the current country's GDP in real-time and accurately (PwC, 2019). If there is an anomaly in the price level, CBDC could notify if the inflation is beyond the target or not (Kiff et al., 2020a). Monetary policy will be quickly responded to the shock due to historical transaction data in CBDC (Bergara & Ponce, 2018). Other data related to economic activity can also be reflected in detail (Goldman Sachs Global Investment Research, 2020). Therefore, CBDC traceability enables us to conduct data analysis that

would provide better decisions for all economic and social sectors (OECD, 2019). Being traceable also could raise AML/CFT concern (Bank, 2019; CEMLA, 2019). Z. Wang (2021) argues that CBDC could reduce tax evasion due to its traceability. Kwon et al. (2020) also argue that CBDC could discourage tax evasion by imposing positive CBDC rates22.

Most of the central banks contradict with fully anonymity CBDC to prevent illicit activities such as money laundering, terrorism financing, etc. (Kaminska, 2021). The Bahamas Sand Dollar CBDC sacrifices anonymity to improve tax administration (Central Bank of the Bahamas, 2019). Southern Caribbean CBDC enables the financial institution to fully observe the identity of both parties (International Monetary Fund. Western Hemisphere Dept., 2020). Sweden also applies an underlying register on e-krona to record the transaction and protect the owner's right, thus it will be traceable (Riksbank, 2021b). However, China plans to use managed anonymity in their CBDC, which means that the transaction will be anonymous if its small value, and will be traceable if its big value (People's Bank of China, 2021).

4.2.2 SWOT Analysis – Weaknesses Aspect

4.2.2.1 High Cost of CBDC Infrastructure

The central bank needs to build the required infrastructure and governance to implement CBDC, this could lead to high operational and associated upfront costs (CPMI, 2018a). The central bank needs to develop a customer interface, front-end wallet, choose and maintain technology, supervise transactions, promote AML, and prevent CFT (Adrian & Griffoli, 2019). Kiff et al. (2020) also found that cost that associated with CBDC is (IT Consulting firm, UI/UX Specialist, Software Developer), infrastructure (cloud and server), software (license and service fees), cyber security (threat modeling, response management, penetration test, identification, and support (helpdesk)[23].

To have the public sector handle technology such as CBDC, would be irrelevant and costly since the private sector keeps innovating, thus it would be relevant to have a Public-Private Partnership (Adrian, 2020). Aside from cost efficiency, some of the other

22 Positive CBDC rate affecting the transfer of seigniorage revenue from transactions that evade sales tax to those who pay, therefore, there will be consumption increment in taxed transactions and consumption declining in non-taxed transactions (Kwon et al., 2020)

23 The high cost is mostly burdened in investment cost. After that, the fixed cost and variable cost will be lower than investment cost

benefits are accessibility to finance, technology transfer, transfer of risk, investment opportunity, and business development (EY, 2015). Morales-Resendiz et al. (2021) also argue that Public-Private Partnership could avoid disrupting private sector innovation. For example, China implements partnerships with the private sector such as commercial banks, mobile payment, and telecom to implement its CBDC (Jiaying Jiang & Lucero, 2021). E-krona from Sweden cooperates with professional consulting companies Accenture and R3 Corda in their CBDC development (Riksbank, 2021a). In its pilot project, ECCB from the Southern Caribbean also conducts a partnership in the procurement of CBDC for its pilot projects (International Monetary Fund. Western Hemisphere Dept., 2020).

4.2.2.2 Privacy Loss

CBDC gives its benefit such as AML/CFT concern and real-time data by its traceability, but it also has some consequences. People tends to maintain their privacy in the CBDC (Borgonovo et al., 2021). In its pilot, Sweden still evaluates the privacy legal aspect to determine which information that CBDC can obtain in the transaction (Riksbank, 2021a). Jiaying Jiang & Lucero (2021) also argue that China's CBDC is still unclear about privacy protection, especially regarding the reporting line when fraud or misused information happened. Even so, most of the authorities would likely disagree to have anonymous CBDC due to the prevention of corruption or any unappealing criminal activities (Birch, 2021). Some example China's retail CBDC is managed anonymity, which the transaction will be traceable if its huge value transaction (People's Bank of China, 2021). Russia also sacrifices anonymity by putting a unique identifier in their CBDC so they can know the movement of the CBDC (Bank of Russia, 2020). Moreover, CBDC that have high privacy will have higher operational costs due to the complexity of their technology (Darbha & Arora, 2020). Privacy issues must be solved by central bank, otherwise people will have reduced trust, thus reduce monetary policy effectiveness due to reduced policy broadness (CPMI, 2018a)

One idea to cater to this anonymity is placing a threshold of a specific transaction amount (Kaminska, 2021). ESCB Eurochain Research Network, Accenture, and R3 are working on a CBDC proof of concept that promotes AML/CFT that is only visible to independent authority (Bank, 2019). China implementing managed anonymity, which means if it's only a small value transaction, it will be anonymous, but it will be traceable when it is a huge value transaction (People's Bank of China, 2021). To maintain public

trust, the central bank could improve its privacy design through third-party reviews of its design and architecture (Darbha & Arora, 2020)

4.2.2.3 Internet Coverage Limitation

Effective CBDC implementation requires related infrastructures such as internet coverage, electricity, and digital ID systems, thus the countries that still not have established infrastructures need to develop it (Didenko & Buckley, 2021). Without proper internet coverage, interest-bearing CBDC can't be implemented since interest payment and deduction needs internet connectivity (Shah et al., 2020). Aside from that, coverage limitation could reduce monetary policy effectiveness due to reduced CBDC coverage (CPMI, 2018a). The central bank would need to either develop its retail and customer service infrastructure or outsource it for distributing CBDC (Wadsworth, 2018). Roller & Waverman (1996) emphasized that the critical mass of telecommunication infrastructure is important for economic growth. Therefore, the required infrastructure needs to be pushed to accommodate CBDC implementation. George, (2018) argues that investment in cable and satellite to cover the internet both in the high-density area or remote area, also as a backup if outage happened.

4.2.2.4 System Failure: Outage

Power has become vital in our modern life, almost every aspect of life relies on power, thus an outage can make our life paralyzed (Küfeoğlu, 2015). The outage could occur from many causes, such as natural disasters and human error (Campbell, 2012; Lawrence, 2021). Lerner (2014) said that the average losses of internet outages are around 5,600 USD per minute and 300,000 USD per hour. Meanwhile, on July 30 and 31 in 2021, blackouts in India affected a huge spread of populations., thus leading to traffic jams, stagnation of tourists, financial transaction disturbance, and losses of up to a billion dollars (Shuai et al., 2018). CBDC means we are being part of modern societies and suffer from the risk of an outage. CBDC is vulnerable to those outages and it will be unreliable in a state of emergency (Wadsworth, 2018). A backup plan is needed to mitigate the unreliability of CBDC when an outage occurs, such as quick resource assignment, planned action plan, and well-prepared recovery procedures (Spivey, 2021). Otherwise, it could disrupt many business activities and thus could have macrcoeconomic consequences. Offline capabilities of CBDC need to be developed in case of an outage (BIS, 2020). As a technical backstop to the CBDC, the central bank should also have a

copy of all CBDC holding so it can be recovered in case of an outage (Auer & Böhme, 2020b)

4.2.3 SWOT Analysis – Opportunities Aspect

4.2.3.1 Growing Technology

Throughout time, the development of financial technology keeps growing and fulfilling the demand of the people (Auer et al., 2020b). For example, Artificial Intelligence (AI) can improve current flow by learning from the pattern and optimizing the result of the activities (Suliman et al., 2019). CBDC could utilize AI in asset management, banking, or another lending platform (An et al., 2021). AI also could be used in data analytics that can supervise and validate risk assessment according to their needs (BIS Innovation Hub, 2021). In a ledger system, blockchain is one of the DLT technologies that can be a storage of all kinds of assets with a high level of security and transparency (Diedrich, 2016). Its immutability attributes on blockchain could be utilized by CBDC to increase resiliency against cyber-attack tampers (Ozdayi et al., 2020). Also, blockchain enables CBDC to conduct seamless Delivery vs Payment transactions (Adrian, 2019). Internet of Things (IoT) enables process automation, integration, reduces labor cost, and also reduces waste (Gilis, 2021). DLT also could enhance financial markets and payment due to its robustness and lower transaction cost, thus make monetary policy more effective (Auer, Monnet, et al., 2021). IoT in CBDC implementation enables us to integrate between various devices such as mobile devices, IC cards, etc. (People's Bank of China, 2021). IoT also enable CBDC to be the basis micropayment for communication protocols interface (Auer & Böhme, 2020b)

4.2.3.2 Network Effect

When there is an adoption of technology that relies on interaction and compatibility within people, the network effect will occur (Easley & Kleinberg, 2010). A network effect is an event of the increasing value of either goods and services when there is an increment in the participant, as an example, the benefit from social networking will be higher depending on how many you connect with other people (Banton, 2021). The same properties applied also to CBDC, the benefits of CBDC will be increased when there is a new user that joins the network due to the network effect (Forner, 2020). Network effect could improve monetary policy effectiveness due to broader coverage, lower transaction cost, and provides better service (BIS, 2021b). Also, an interest-bearing CBDC

alleviates the central bank's trade-off when network effect matters24 (Agur et al., 2021). There is another critical concern on the network effect, declining cash usage has become a disruption for the central bank in the presence of network effects (Agur, Ari, & Ariccia, 2019). With the declining cash usage network effect, commercial banks may ATM will be obsolete and the merchant will no longer accept cash, thus cash may disappear when its use falls below a critical threshold, this phenomenon is happening in Sweden (Riksbank, 2020).

4.2.3.3 CBDC Enthusiasm

A lot of central banks are interested in developing CBDC, and their progress starts from research, pilot, proof-of-concept until live implementation (Boar & Wehrli, 2021; Kalfon et al., 2021). CBDC has become global attention and featured in a lot of central banks' communications and public interest[25]. The technology of CBDC and how they related to the private sector has become a huge discussion (Auer et al., 2020b; Gross et al., 2020; Vives, 2019). Moreover, the growth of fintech companies is expected to reach a superlative annual growth rate of 12 percent by 2026 (Market Data Forecast, 2021). Adrian (2020) argues that to have public sector development handle technology is irrelevant and costly due to the private sector innovation, thus it will create wider opportunities to create partnerships with private entities such as fintech companies. The private sector will gain knowledge transfer that can benefit them in the upcoming project (World Bank, 2020). Public-private partnerships also give unique risk-sharing arrangements and encourage private companies to invest in the bigger project (Y. Chauhan & Marisetty, 2019).

Those enthusiasms can be seen by many CBDC development conducting Public-Private Partnership and show that openness from the private sector. E-krona from Sweden using Accenture and R3 Corda as the partner of developing their CBDC in the pilot stage (Riksbank, 2021a). Commercial banks, mobile payment services, and telecom companies are used by China in developing their pilot project (Central Bank of Indonesia, 2021; Jiaying Jiang & Lucero, 2021). Project Helvetia from Swiss-France with BIS are

24 When interest-bearing CBDC was optimally designed, it would safeguard from bank intermediation and protecting the trio of payment instruments from network effects, regardless of the financial friction role in the economy (Agur, Ari, & Dell'Ariccia, 2019)

25 Research from Auer et al. (2020) was using moving sum and average approach of CBDC speeches, report, and search interest from 2016 – 2020 to determine CBDC as the global attention

cooperating with Commercial Banks that joined in "SIX" to join in their development stages (BIS et al., 2020). Last but not least, Thailand picks Giesecke+Devrient to develop its retail CBDC (Central Banking Newsdesk, 2021b).

4.2.3.4 Cash Inefficiency

The retail transaction that uses cash is keeps declining from 2006 to 2019 due to its convenience in using digital money (Auer et al., 2020a; Wolf, 2021). Aside from convenience, cash has disadvantages such as the risk of theft, high cost of maintenance, and inefficient distribution (Brugge et al., 2018). Covid-19 pandemic also hastens the declining usage of cash due to physical distancing protocol (Torry, 2021). By these phenomena, CBDC would be an alternative of the payment instrument to retain central bank-issued money access (ING Group, 2020). Even though the cash keeps declining, most of the payments still use cash, however, Shekhar et al. (2020) found that the acceptance of the cashless system is dominated by the younger consumer. This means that the next generation will prefer using a cashless system and it has huge potential for CBDC acceptance in near future. However, aside from its opportunity, declining cash usage must gained a traction for central bank, otherwise central bank could loss their monitoring towards money circulation (Beau, 2021)

There are some examples of the cash declining phenomenon in other countries. By 2020, only 9 percent of the transaction in Sweden that still using cash (Riksbank, 2020). Declining cash usage in Sweden makes rejection of cash in many stores and several commercial banks won't collect or disburse cash (Skingsley, 2016). United States cash usage also keeps declining to 18 percent in 2020, and it's get fostered due to Covid-19 (Coyle et al., 2021). Declining also happened in the UK when since 2017 the cash usage keep declining by 15 percent per year (Barret, 2021).

4.2.4 SWOT Analysis – Threats Aspect

4.2.4.1 Cyber Attack

As the technology advanced through time, there will always be an effort to exploit the technology for personal gain, which means the risk of cyberattack is always exist (Australian Computer Society, 2016). Cyberattack is an attack to compromise the confidentiality, integrity and availability of data through internet (Bendovschi, 2015). Cyber security is an important aspect for CBDC to secure storage, value transfer, privacy, and resilience (Minwalla, 2020). This need to be taken seriously because in US, people tend to trust traditional financial institutions rather than the government agency in term

of data protection (Armantier et al., 2021). Moreover, payment sector is the most frequent target of cyberattack (Aldasoro et al., 2021). Auer & Böhme (2020) found that CBDC has a vulnerability to massive DDoS (Distributed Denial of Service) attacks that cause system delays in carrying out the transaction process. DDoS is a deliberate attack that makes both the network and system unavailable for an authorized user, which opens an opportunity for the hacker (Tripathi & Mehtre, 2013). Cyberattack also could affect financial stability by disruption in payment, settlement, and clearing of CBDC (CPMI, 2018a). This scenario could be worsen because CBDC covers a huge amount of users., thus it will make the system more vulnerable. (Collet et al., 2020).

Rigorous efforts must be implemented to enhance the cyber security of CBDC such as RegTech (Regulatory Technology) and SupTech (Supervisory Technology) (Central Bank of Indonesia, 2019). The security must be assured through sustainable testing, authentication, best practice, and have a period of system components audit (Minwalla, 2020). Moreover, CBDC will be a high-value target since its carry public identity information. Multi consensus like DLT can be adapted to prevent cyber-attack, especially regarding data fraud (Bank of England, 2020). In conclusion, all the gaps that can create weakness points of cyber security must be assessed and solved. Even though all the research, proof-of-work, pilot, and live implementation doesn't experience cyber-attacks that occurred in CBDC, the central bank must be aware of cyber security and vigilant with the potential.

4.2.4.2 Bank Disintermediation

Bank disintermediation happens when depositor no longer deposit their money on banks (Choulete & Shulyatyeva, 2016). This can happen if the depositor is more interested to move their money in CBDC rather than in the bank. CBDC has similar characteristics to bank deposits in both interest-bearing and non-interest bearing terms (Agur, Ari, & Dell'Ariccia, 2019). This characteristic creates a threat and bank run could happen. If the economy is getting worse, users will tend to move their assets from commercial banks to CBDC because CBDC is the liabilities of the central bank and central bank is LOTLR. This phenomenon can disrupt bank liquidity due to a sudden contraction in commercial banks, especially with CBDC the settlement process becomes instant (Bitter, 2020).

However, Viñuela & Sapena (2020) research argues that the threat from bank disintermediation can be mitigated by promoting the transition of CBDC from the current

two-tier fractional reserve banking system to a full reserve banking system. Implementing capacity on the CBDC wallet and lowering the CBDC rate is also one of the efforts to prevent deposit crowds out (Sandbu, 2021). But, implementing CBDC capacity would likely trigger political pressure during the time of crisis (ING Group, 2020)

4.2.4.3 Unprepared Legal Aspects

CBDC implementation would likely raise an issue in legal aspect as highlighted by the central bank or related policymakers, the issue is varying from ownership of authority, the realness of CBDC, and legality of CBDC, thus the fintech would likely be dominated by private entities (Bossu et al., 2020). The amount of information collected from CBDC also becomes a critical issue, such as how much information can be taken or how people could sue if there is any fraud or misused information (Jiaying Jiang & Lucero, 2021; Riksbank, 2021a). Moreover, current CBDC technology is not adequate to handle privacy protection issues, thus could create a conflict (Shirai, 2019a). There's some use case about the legal aspect that can threaten CBDC issuance. Privacy protection regarding CBDC is still unclear in China. It is unclear how people could investigate or sue when there is fraud or misuse of their information (Jiaying Jiang & Lucero, 2021). PBOC or related authorities should be the ones who monitor compliance within the transaction and protect their information. In the pilot test, Sweden still faces some legal issues. The lesson learned from the legal aspect was Riksbank must be a guarantor of CBDC value even though there's already an intermediary. Also, Riksbank must protect transaction information in bank secrecy and avoid exposing data (Riksbank, 2021a). Not only retail CBDC, proof of concept in wholesale CBDC also raises numerous legal and policy questions regarding issuance, transfer, and redemption of wholesale CBDC (BIS et al., 2020). Privacy issues must be solved by central bank, otherwise people will have reduced trust, thus reduce monetary policy effectiveness due to reduced policy broadness (CPMI, 2018a). It can be concluded that CBDC issuance must raise a concern of clear, transparent, and enforceable legal basis as governed by (CPMI, 2017).

4.2.4.4 Private Crypto-asset Competition

The emergence of private crypto-asset such as Libra creates attention from authority to increase the priority of retail CBDC (Morales-Resendiz et al., 2021). The characteristics of cryptocurrency are electronic, not central bank liabilities, and peer-to-peer (CPMI, 2015). It also has some social costs that concern the central bank (Agur, 2018). First, the high volatility of private crypto-asset such as Bitcoin makes it not viable

as a stable means of payment (He et al., 2014). Second, the tragedy of Bitcoin exchange collapse such as Mt. Gox addresses the operational risk of private crypto-asset (Hu et al., 2020). Third, high power consumption due to its mining. For example, Malone & O'Dwyer (2014) found out that Bitcoin mining consumes around 5 gigawatts (the same amount as Ireland's electric consumption in early 2014). Fourth, private crypto-asset anonymity raises AML/CFT concerns (Agur, 2018). Fifth, the private crypto-asset has poor scalability if the number of transactions grows exponentially (A. Chauhan et al., 2018). Sixth, the central bank would likely lose its sovereignty if private crypto-asset become wider means of transactions[26] (Gross & Schiller, 2020).

The anonymity offered by cryptocurrency also being one of the reasons why it is feasible for some people (Agur, 2018; Goodell & Aste, 2019). People also don't have enough faith in CBDC data protection, therefore, they choose cryptocurrency as an alternative (Gasbeke, 2021). When people tend to use private crypto-asset that central bank money, the central bank can't monitor its circulation, which will raise the issue of AML/CFT (Gross & Schiller, 2020). Aside from the criminal activities, if the central bank loses control of money through monetary policy, thus could lose control of the currency too. (Woodford, 2000). Effectiveness of monetary policy could be reduced due to the autonomous decision by private crypto-asset (Tomić et al., 2020). Due to those concerns, some of the countries also consider banning cryptocurrency (Houben & Snyers, 2018). Even though cryptocurrency is threatening for CBDC, the central bank still can take the advantage of cryptocurrency technology (Auer & Böhme, 2021). Cryptocurrency such as Bitcoin is well-known due to its blockchain usage in their transaction. It's offer resilience, security, and transparent attribute that can be beneficial for CBDC development (Politou et al., 2019). A country such as Sweden, Singapore, Canada, and Hongkong also make a partnership with R3 Corda to develop blockchain on their pilot testing (Atlantic Council, 2021).

26 It can be seen from around 7500 private digital currency is emerged until now, which means the central bank did not have any surveillance on it (Gross & Schiller, 2020)

4.2.5 Optimal CBDC Design

Based on those explanations of each SWOT aspect, we could make a SWOT analysis, however, this research wants to conduct a SWOT analysis on each possible CBDC design. Therefore, the SWOT analysis will be conducted in the form of a matrix, so we could know which CBDC characteristics that have the attributes of each SWOT aspect. See Table 3.3 for the legends and see Appendix A for the references of SWOT matrix and

	Coverage		Remuneration		Payment System		Anonymity		Architecture			Ledger System		Scope	
	Retail	Wholesale	Interest-bearing	Non-interest bearing	Account-based	Token-based	Anonymous	Traceable	Indirect	Direct	Hybrid	CLT	DLT	Domestic	Cross-border
Strengths															
Payment Efficiency	0.75	0.75	1	0.25	0.5	0.75	0.25	0.75	1	0.75	1	1	0.75	0.5	0.75
Monetary Policy Effectiveness	0.75	0.25	1	0.25	0.75	0.25	0.5	0.75	0.25	0.75	0.75	0.75	0.25	0.5	0.75
Increasing Financial Inclusion	1	0	0.75	0.75	0.75	1	0.75	0.5	0.75	0.5	0.75	0.5	0.75	0.5	0.75
Traceability	0.75	1	0.75	0.5	1	0.75	0	1	0.25	0.75	0.5	0.5	0.75	0.5	1
Weaknesses															
High Cost of CBDC Infrastructure	-0.75	-0.5	-0.75	-0.5	-0.25	-1	-1	-0.25	-0.5	-0.75	-0.5	-0.75	-0.25	-0.5	-0.75
Privacy Loss	-0.75	-1	-0.75	-0.5	-1	-0.75	0	-0.75	-0.25	-0.75	-0.5	-0.5	-0.25	-0.75	-1
Internet Coverage Limitation	-1	-0.25	-1	-0.25	-1	-0.75	-0.5	-0.75	-0.5	-0.75	-0.5	-1	-0.75	-0.75	-1
System Failure: Outage	-0.75	-1	-1	-0.75	-1	-0.75	-0.5	-0.75	-0.5	-0.75	-0.5	-1	-0.75	-0.5	-0.75
Opportunities															
Growing Technology	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Network Effect	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CBDC Enthusiasm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cash Inefficiency	1	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Threats															
Cyber Attack	-1	-0.75	-0.75	-0.5	-0.5	-0.5	-0.5	-0.75	-0.75	-1	-0.75	-1	-0.25	-0.5	-0.75
Bank Disintermediation	-0.5	0	-0.5	-0.25	-0.75	-1	-0.75	-0.5	-0.5	-0.25	-0.5	-0.5	-0.75	-0.5	-0.75
Unprepared Legal Aspect	-1	-1	-1	-0.75	-0.75	-0.5	-0.5	-0.75	-0.5	-0.75	-0.5	-0.5	-0.75	-0.5	-0.75
Private Crypto-asset Competition	-1	0	-0.25	-0.75	-0.75	-0.5	-0.25	-0.75	-0.25	-0.5	-0.25	-0.5	-0.25	-0.75	-0.25
Total	**0.5**	**0.5**	**1**	**1**	**0.5**	**0.5**	**1**	**1.25**	**2**	**0.75**	**2.5**	**0.5**	**2**	**0.75**	**0.75**

Table 5 General SWOT matrix calculation

Source: Constructed by author

Based on the calculation of SWOT points, it can be seen the most beneficial design of CBDC. Both retail and wholesale coverage carry the same score, it means that we could either choose both of them or just one of them. Both interest-bearing and non-interest bearing remuneration also achieve the same score, which means both of them are feasible and could be choose both or one of them. The account-based and token-based payment system achieve the same score, thus it would be feasible for both options[27]. The traceable anonymity would be the most feasible characteristic. The architectures would be hybrid. The ledger system would be DLT. Lastly, we could choose either domestic or cross-border scope. The most optimal design would be depending on the rationale in the next paragraph

Characteristics	Points
Coverage:	
A: Retail	0.5
B: Wholesale	0.5
Remuneration	
C: Interest-bearing	1
D: Non-interest bearing	1
Payment System:	
E: Account-based	0.5
F: Token-based	0.5
Anonymity:	
G: Anonymous	1
H: Traceable	1.25
Architecture:	
I: Indirect	2
J: Direct	0.75
K: Hybrid	2.5
Ledger System	
O: CLT	0.5
P: DLT	2
Scope:	
Q: Domestic	0.75
R: Cross-border	0.75

Table 6 Calculated Point of SWOT Analysis

Source: Constructed by author

[27] Both account-based and token-based payment system receive zero score, however it doesn't mean both of the characteristics have no value. Its merely a result of positive and negative value from SWOT scoring, and we only consider which one of them is higher/same/lower regardless the outcome number.

Based on those concerns, we can conclude that the most optimal design is to develop both retail and wholesale CBDC that needed to implement together. Aside from the fact that both retail and wholesale coverage are being most beneficial based on SWOT points, it is aligned with BSPI 2025 initiative regarding the second initiation about retail payment, and the third initiative about financial market infrastructure. Limitations such as unequal financial inclusion could be solved, and also able to achieve more efficiency in the interbank transaction. Related to the poor internet coverage, wholesale CBDC could be implemented first while waiting for the development of internet coverage[28]. Implementing both retail and wholesale also same as utilizing potential coverage, thus make monetary policy more effective

The remuneration will be both interest-bearing and non-interest bearing. The CBDC would be interest-bearing for the wholesale CBDC, while non-interest bearing will be implemented in retail CBDC. Wholesale CBDC is used in interbank transactions such as wholesale payment, reserve, interbank load, and so on, thus it is required to be interest-bearing. Meanwhile, non-interest bearing would be fit for retail CBDC because it has less risk of bank disintermediation and is also aligned with the PMFI principle to aim the financial stability. The non-interest bearing payment system could more support financial inclusion due to the possibilities of conducting offline transactions, thus it could reach low connectivity areas such as remote areas and reach broader financial inclusion. After all, both interest-bearing and non-interest bearing carry the same score which means both of them are feasible to be implemented

Account-based must be implemented with token-based payment systems. Both account-based and token-based got the same score, which means it's feasible for both implementations. Account-based has more resilience against cyberattacks, and it's needed to mitigate the weak cyber security system. The account-based payment system also supports AML/CFT concerns, which are aligned with PFMI regarding the public policy objectives. Due to the least information that needs to be covered, account-based CBDC has lower implementation costs, thus it will be more cost-saving. However, it needs to implemented with the token-based payment system. Token-based can conduct an offline transaction, which could temporarily solve the limited internet coverage, thus it could also promote financial inclusion due to the broader distribution up to the remote area.

[28] Even though we could implement token-based, account-based also need to be developed to raise the concern of AML/CFT

Maximizing coverage area also imply more effective monetary policy transmission due to CBDC coverage broadness

The degree of anonymity will be traceable. First, it could prevent illicit activities such as supporting AML/CFT, and also it is aligned with the PFMI public policy objectives. Second, the infrastructure of traceable CBDC is less expensive than the anonymous one. This is because traceability means less information that needs to be covered, thus it more cost less than the anonymous one. Third, traceable CBDC allows the central bank to extract real-time data of CBDC, and it could make the central bank make a quicker response of monetary policy and able to has the smarter decision in policymaking. After all, the traceable CBDC has more scores than the anonymous one

The architecture would be hybrid CBDC. The distribution of retail CBDC is using hybrid architecture, in which distribution of CBDC and KYC is handled by the other intermediaries, but the central bank still periodically checks its retail transaction. This scheme allows us to implement Public-Private Partnership thus it won't harm innovation and more efficient CBDC implementation. Retail CBDC involves the whole people transaction, which means larger broader of the transaction, thus we could not have a bigger risk of single point failure in a retail transaction. Also, hybrid architecture offers broader monitoring for the central bank because the central bank would periodically check the retail transaction, unlike indirect architecture that only focus on wholesale transaction, and unlike direct architecture that has complex operational. Moreover, by central bank handling retail transaction means it could apply monetary policy effectively because central bank could react from the real-data information

The ledger system would be DLT. First, it is more resilient from an outage due to less risk of single point failure. DLT has decentralized nature, not like CLT who has centralized nature which has a bigger single point of failure risk. Second, DLT enables us to use blockchain technology, the blockchain technology only available on the DLT ledger system. Blockchain technology uses the block that chained each other by hash, each created block need to pass the validation through the consensus, thus it could be more resilient from cyberattacks due to its immutable attribute. After all. The DLT ledger system has more scores than CLT. From monetary perspective, robust system of CBDC also prevent the risk from cyberattack that could disrupt payment, settlement, and clearing, thus could create financial instability

The scope would be both domestic and cross-border. Both of them have the same score and are possible to have implemented each other. Also, implementing both of domestic and cross-border could support monetary policy due to its benefit. Domestic CBDC could promote financial inclusion with a reduced transaction cost, meanwhile, cross-border CBDC could reduce the cost of remittance and improve the settlement speed. Cross-border CBDC also supports interoperability which enables us to offer a larger payment ecosystem. The network effect also could be optimized due to the broader interoperability that reaches the overseas ecosystem. Moreover, it is also aligned with the PFMI principle related to communications procedures and standard.

4.2.6 CBDC Implementation Strategies

SWOT analysis in the previous section does not only result in optimal CBDC design but also could be derived into SWOT strategies to optimize the SWOT analysis result. By proposing SWOT strategies, we could seize the potential opportunities and mitigate the potential threat created from CBDC implementation, which also could become a policy recommendation. All of the strategic actions are concluded into 4 main points as follows:

	Actionable Steps	
	Strengths: 1. Payment efficiency 2. Monetary policy effectiveness 3. Increasing financial inclusion 4. Traceability	**Weaknesses:** 1. High cost of CBDC infrastructure 2. Privacy loss 3. Internet coverage limitation 4. System failure: Outage
Opportunities: 1. Growing technology 2. Network effect 3. CBDC enthusiasm 4. Cash inefficiency	**Strategies:** • Adapt with every emerging technology and learn other CBDC development to improve CBDC (S1, S3, O1, O3) • Using both account and token based to broaden CBDC distribution so network effect will effective (S3, O2) • Gradually convert merchant to CBDC so it will drive people to use CBDC (S1, S3, O2, O4)	**Strategies:** • Utilizing IoT to improve device integration for broaden CBDC coverage (W3, O1) • Keep adapt and learn from emerging technology and other CBDC development to keep improving user data protection (W2, O1, O3) • Utilizing backup cloud server to ensure backup plan when outage happened (W4, O1) • Proposing Public-Private Partnership to reduce cost of CBDC infrastructure (W1, O3)

Threats: 1. Cyber attack 2. Bank disintermediation 3. Unprepared legal aspect 4. Private crypto-asset	**Strategies**: • Cost of cash handling could be allocated to improve cyber security, so it will mitigate cyberattack (S1, T1) • Implementing capacity on CBDC wallet to make CBDC only used as a means of payment, also won't faster the bank run when crisis happened (S2, T2) • Ensuring the law of which information that will be traced and improving data security, and electing independent data authority to gain public trust (S4, T3, T4)	**Strategies:** • Ensuring backup plan so it won't be vulnerable to cyberattack when outage happened (W4, T1, T4) • Ensuring the law of which information that will be traced and improving data security, and electing independent data authority to gain public trust (S4, T3, T4) • Proposing Public-Private Partnership to reduce cost and allocate it to improve cyber security (W1, T1)

Table 7 SWOT Strategies Implementation

Source: Constructed by author

4.2.7 Strength – Opportunities Strategies

In this step, we will use the internal strength and utilize available opportunities. First, the growing technology introduce us many innovations that make our life easier. The only problem is, how can we adapt with every technology so we could keep improving CBDC. For example, by using AI, we could identify pattern from current payment system and calculate the possible way to gain more efficiency. Those insight will help CBDC to gain more efficiency by implementing that insight. With IoT, the government could directly transfer aid to the related user with less intermediaries. IoT enable the integration of many devices. Meanwhile, blockchain could give us efficiency in the ledger system that can reduce the intermediaries in transaction. Moreover, blockchain also carry the properties of immutable and hard to tamper with. Aside from technology, CBDC enthusiasm also provide us many new insights that could be useful for CBDC development. Any success or failure of CBDC development could be extracted into lesson learned.

CBDC also offer such as financial inclusion by transforming unbanked and underbanked into banked, thus increase the CBDC users. The network effect will unleash potential of CBDC when there is an increment in CBDC users. Improving internet coverage will help us to maximize this potential by investing in cable and satellite infrastructure, so the people on both high density and remote area could be covered, therefore the network effect will be unleashed. However, the improvement of internet coverage will take time. Therefore, implementing both account-based and token-based could be solution. Account-based CBDC is more resilient, also less expensive in term of operational cost, however, it relies on the internet connection. So, implementing token-based will help alleviate the alternative means of payment because token-based CBDC

enable us to conduct offline transaction. In conclusion, we could maximize the CBDC distribution so the network effect of CBDC will be effective

Network effect could give the unleashed a new potential when the number of users is increased. The more users increasing, the more benefit that can be obtained. Also, declining cash usage shows us cash is being an inefficient compared to CBDC by the term of transaction cost. Converting merchants into CBDC payment will drive people to convert CBDC because people need CBDC to conduct a transaction. Moreover, using CBDC also more beneficial than using cash.

4.2.8 Weaknesses – Threats Strategies

In this step, we work to mitigate our weaknesses so we can avoid the incoming threat. Every technology is carrying the risk of cyberattack, however, when the technology is experienced downtime, it will be more vulnerable from cyberattack, including CBDC. The central bank needs to prepare any backup plan when outage happened. The backup could be in form of backup file that saved in both could server and external devices such as hard drives. Also, the central bank could implement geo-replication, so when outage happened, it won't be concentrated in the one place.

Legal aspects being a concern in CBDC implementation. Sweden has issue in legal aspect because there is no jurisdiction that govern Riksbank as a value guarantor of e-krona and amount of information that could be extracted. China also faces the legal issue due to the uncertainty in the settlement when there is misused data. Therefore, the central bank needs to expose which information that could be extracted from CBDC and make the legal jurisdiction about it. Also, the technology of cyber security needs to improve as an effort of data protection. The data operator should be independent but verified by central bank, so it could reduce the fraud potential and gaining public trust.

Implementing CBDC is costly due to its infrastructure. CBDC implementation needs to develop customer interface, front-end wallet, choose and maintain technology, supervising transaction, promoting AML/CFT. CBDC infrastructure also consist of IT (Consulting firm, UI/UX Specialist, Software Developer), infrastructure (cloud and server), software (license and service fees), cyber security (threat modelling, response management, penetration test, identification, and support (helpdesk). If the central bank handles those technology, it won't be efficient because aside from the high upfront cost, it will be irrelevant because the private sector keeps innovating and its hard to balance it.

Therefore, Public-Private Partnership become the option for central bank to develop CBDC. Implementing Public-Private Partnership also won't harm innovation of private sector. Moreover, the cost-saving from Public-Private Partnership also could be allocated to improve cyber security, so it will be more resilient against cyberattack.

4.2.9 Weaknesses - Opportunities Strategies

Weaknesses can be mitigated if we could utilize the available opportunities. CBDC relies on the internet connectivity, especially account-based CBDC. Having limited internet coverage will be an obstacle for the CBDC distribution. Improvement of internet infrastructure is needed because IoT could enhance the CBDC distribution. IoT enable us to create an integration between many devices such as RFID, sensor, and wireless device. IoT integration will enhance the CBDC distribution and make the internet coverage more effective and efficient

Data protection is an important point for CBDC implementation, but there is no technology that can avoid the risk of cyberattack. If the data is leaked due to the cyberattack, the people will lose its privacy, thus the public trust will reduced. The central bank needs to keep adapt with growing technology since the technology always evolving, and the threat also evolving. The enthusiasm of CBDC development also bring new insights if we could extract their lesson learned, either it is success or failed. The central banks need to be adaptive and keep their eagerness of learning if they want to keep improve CBDC, especially about data concern.

Growing technology could give us the options to solve the problem, including in CBDC. Outage in CBDC could be critical due because it is responsible for whole people transaction. CBDC downtime could disrupt whole transaction, creating panic, and loss to the business. Technology such cloud server enables us to create copy from our hard drives. However, hard drives also enable us to create copy if the cloud server is down. Implementing geo-replication also could reduce the severeness of outage because it won't make the outage to be concentrated in one place.

CBDC infrastructure is costly due to the development of customer interface, front-end wallet, choose and maintain technology, supervising transaction, promoting AML/CFT. CBDC infrastructure also consist of IT (Consulting firm, UI/UX Specialist, Software Developer), infrastructure (cloud and server), software (license and service fees), cyber security (threat modelling, response management, penetration test, identification,

and support (helpdesk). CBDC infrastructure also consisting of (IT Consulting firm, UI/UX Specialist, Software Developer), infrastructure (cloud and server), software (license and service fees), cyber security (threat modelling, response management, penetration test, identification, and support (helpdesk). By doing partnerships with private entities, especially fintech, the cost of procurement can be shared with the private entities. Moreover, the enthusiasm of CBDC could be example that private sector also interested with the CBDC development

4.2.10 Strengths - Threats Strategies

By utilizing our internal strengths, the revealed threats can be mitigated. Using DLT could reduce the number of intermediaries. Also, CBDC has less cost of handling and maintenance if it compared with cash. However, every technology will carry the risk of cyberattack, including CBDC. Therefore, the central bank needs to concern about the cyber security. By utilize from the CBDC cost reduction, the central bank could allocate the surplus to improve cyber security, thus CBDC will be more resilient from cyberattack.

CBDC would likely to give benefit to its users, moreover, it is considered as a risk-free asset because it is a direct claim to central bank. Due to its attributes, there will be a potential when crisis happened, people will convert their asset to CBDC, thus creating bank disintermediation. CBDC also could make the bank disintermediation quicker because people could instantly 24/7 withdraw their deposits to CBDC, unlike current ATM that have a distance limitation and withdrawal capacity. Implementing capacity in CBDC wallet will prevent people to fully convert to CBDC, and it will mitigate the bank disintermediation

Data privacy and protection is being a concern in CBDC implementation, for example cases in China and Sweden when they conducted pilot testing. Legal aspect regarding to the data need to govern how much information that could be extracted, and the settlement when there is any misused in data management. Protecting data privacy and security could increase the public trust. Maintaining public trust is important because people could rather use private money if the central bank can't keep their credibility.

5. Concluding Remarks

5.1 Conclusion

The development of CBDC has been conducted by central banks across the world with various progress and motivation. From that consideration, implementing CBDC would likely to have an impact on macroeconomy consequences and monetary policy implication. However, it needs a comprehensive solution to support monetary policy based on those impacts. Therefore, the objective of this research is to quantify the macroeconomic consequences and monetary policy implication in the presence and absence of an interest and non-interest bearing CBDCs in competing with cash and bank deposits, followed by designing optimal CBDC design and its implementation strategies to support monetary policy. The result of this research could contribute as a reference for related policymakers and future researcher as they outline the CBDC optimal design to support monetary policy

DSGE simulation from both productivity and interest-rate shocks implies that CBDC would likely improve monetary policy transmission. Improvement comes from the attractiveness of CBDC because household tend to substitute deposit to cash and CBDC due to the consideration of risk-free assets. CBDC also could foster consumption, thus increase the national output. However, it depends how CBDC design could support monetary policy

As the steps to determine optimal design, this research presented the overview of general SWOT analysis from various research and development of CBDC across the world. The SWOT analysis can be highlighted by strengths: payment efficiency, monetary policy effectiveness, financial inclusion, and traceability; by weaknesses: high cost of CBDC infrastructure, privacy loss, internet coverage limitation, and system failure: outage; by opportunities: growing technology, network effect, CBDC enthusiasm, and cash inefficiency; by threats: cyber-attack, bank disintermediation, legal aspect, and private crypto-asset. Each of the SWOT aspects will be weighed by the score on each CBDC characteristics, the score was decided from various references such as its characteristics, limitation, and lesson learned from other countries that either support or deny its aspect.

After those consideration, optimal CBDC design could be decided. The design are retail and wholesale coverage, interest-bearing and non-interest bearing remuneration,

account-based and token-based payment system, traceable anonymity, hybrid architecture, DLT ledger system, and domestic and cross-border scope.

The SWOT analysis above can be derived into four possible strategies. The SO strategy is focused on enhancing CBDC technical by utilizing current phenomenon and trend that can be advantageous for us. The WO strategy is focused on determine the possible drawback of CBDC implementation and mitigate it by utilizing advantageous opportunities. The ST strategy is focused on maximizing CBDC technical to mitigate possible threats that will disrupting CBDC existence. The WT strategy focused on determine and minimizing possible drawback of CBDC implementation to mitigate the possible threats. Policy implication and recommendation for actionable items could be extracted from those possible strategies.

This research has limited empirical view of CBDC live implementation. First, macroeconomic consequences and monetary policy implication of CBDC only extracted from the general equilibrium models simulation. Second, the countries that already in live CBDC implementation are only Bahamas and Eastern Caribbean, the rest is still on research, pilot, and proof-of-concept. Therefore, this topic still has a good exploratory as the CBDC development goes by. There will be advanced research using more empirical data and new lesson learned from advanced CBDC development. New proposed design is also possible when there is new insight

5.2 Policy Implication and Recommendation

Based on the proposed CBDC optimal design, there are some policy implications that can be obtained and some recommendations that could be applied, so it could support monetary policy. First, CBDC implementation would likely to increase budget spending due to its high cost of infrastructure, and also it would disrupt innovation. Therefore, proposing Public-Private Partnership allow us to maintain innovation, and also increase efficiency. The partnership could be with state-owned enterprises or private entities. Second, implementing CBDC implies that people could access their money in 24/7, which means it make the people to withdraw their money anytime and anywhere in the time of crisis. Implementing capacity on the CBDC wallet could prevent people to withdraw all their deposit to CBDC so it won't create bank disintermediation. Third, implementing alternative offline payment such offline token-based CBDC implies that people need to raise their awareness of their own key because if the owner lose the key,

it means the owner lose all of its funds. Implementing low capacity on offline token-based CBDC could reduce the severeness level of loss in case they are miss their own key. Fourth, implementing traceable CBDC implies that the central bank needs to govern how much information that could be extracted and which authority that eligible to operate CBDC. The legal aspect of CBDC issuance must be adjusted, also the chosen authority must be independent to gain public trust. Fifth, CBDC is the result of technology innovation, which means it carries single point of failure risk and implies to CBDC operational. Prevention from central bank is needed by providing any means of backup plan so there will be no downtime in CBDC implementation. Sixth, implementing DLT ledger system implies that central bank doesn't has full control due to the consensus mechanism, moreover if it permissionless like Bitcoin. Therefore, CBDC could use permissioned DLT so the validator of the transaction will be known and authorized, thus more controllable. Lastly, implementing cross-border payment implies that our CBDC must able to achieve interoperability to the other countries currency. Thus, the central bank should able to align their clearing mechanism and has shared technical interface, however, the central bank needs to ensure that the integration between two system will not weakened our sovereignty

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