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by

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Abstract

This paper explores three monetary and financial issues of retail central bank digital currency (CBDC) in the Thai context. The first insight shows that opportunities in the digital age may arise for Thai citizens and businesses to reap the benefits of a more efficient form of public money and financial innovation. It is possible for Thai citizens to quickly adopt unremunerated CBDC for transactional use within a decade. Second, we point out that there are several ways to utilize retail CBDC for enhancing monetary policy effectiveness, namely, through the bank rate channel and the introduction of new monetary policy tools. Nevertheless, monetary policy should not be the first and foremost objective for the central bank to issue CBDC as there are other factors to consider. These included impacts on the central bank balance sheet and monetary operations, especially for remunerated CBDC. Disintermediation and liquidity risks for Thai financial institutions are also key concerns, which are discussed in the third part. We assess that the risks to the banking sector are low in normal periods, but the well-designed CBDC features are necessary to prevent mounting liquidity risks in distressed periods.

Keywords: CBDC, digital currency, digital money, financial landscape, monetary policy, financial stability

JEL Classifications: E41, E42, E52, E58, G21

The opinions expressed in this paper are those of the authors, and do not necessarily represent those of the Bank of Thailand nor the Puey Ungphakorn Institute for Economic Research.

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1. Introduction

The digitalization of money and payment has continuously evolved in the modern era. Payment innovations began with credit cards in the 1950s, while later innovations were seen in magnetic strips on plastic cards and bank accounts. In 1998, internet payments for online shopping were enabled by PayPal, while mobile payments began with M-Pesa in 2007. Up to that point, innovation had built on sovereign currencies issued by governments.

More recently, developments in financial technology shifted more toward private issued currencies that have cross-border reach. In 2008, the distributed ledger technology (DLT) was applied to finance, leading to the rise of cryptocurrencies. For instance, DLT was used as the underlying technology of Bitcoin, the first and still the most traded cryptocurrency (Assenmacher, 2020). However, volatile prices undermined the usefulness of cryptocurrencies as store of value and medium of exchange. To reduce this disadvantage, fiat or safe asset-backed private stablecoins were introduced, limiting price volatility and becoming better store of value.

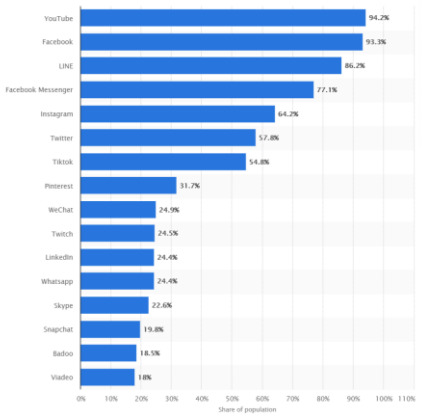
Stablecoins received widespread attention after Facebook announced a plan in June 2019 to launch Libra as a global currency, pegged to a basket of stable currencies. Libra would facilitate cheap payments through Facebook's global platform and reach global-scale adoption. However, after facing much scrutiny from global regulators, Libra was renamed as Diem and would launch in 2021 as a USD-backed stablecoin.

Meanwhile, for some countries, digitalization has been led increasingly by non-bank private platforms. In China, 86% of consumers use mobile payments to make purchases (PWC, 2019). The market is dominated by two mobile apps, WeChat Pay and Alipay, accounting for 94% of all mobile payments (Chen & Huang, 2019). Increasingly, financial intermediation and other financial activities are being conducted through these platforms. Concerned with the trend, the People's Bank of China planned to launch the Digital Currency Electronic Payment (DCEP) for nationwide usage by 2022. DCEP would become one of the world's first retail central bank digital currencies (CBDC). Furthermore, DCEP could also be used to advance the internationalization of the renminbi.

Thailand has not been an exception to the rapid digitalization of the financial ecosystem (Moenjak, et al., 2019). E-money exhibited growth rates of more than 30% in terms of volume and value (Bank of Thailand, 2019). 67% of the population now access mobile payments, making Thailand second only to China in global mobile payment ranking (PWC, 2019). Big tech companies see fast growth and benefit from their large network platforms. These enabled them to establish joint-partnerships with traditional banks to offer new financial services, such as LineBK (Kasikorn Bank and Line) and KKP-Start Saving (Kiatnakin Bank and TrueMoney).

Looking forward, the roles of private-issued or foreign digital currencies in Thailand could increase substantially. First, Thailand is already one of the countries with the highest social media penetration in Southeast Asia, with YouTube and Facebook having respective penetration rates of 94.2% and 93.3% in January 2021 (Figure 1). It is possible that if private currencies emerged from these platforms, they would gain significant market share among Thai users.

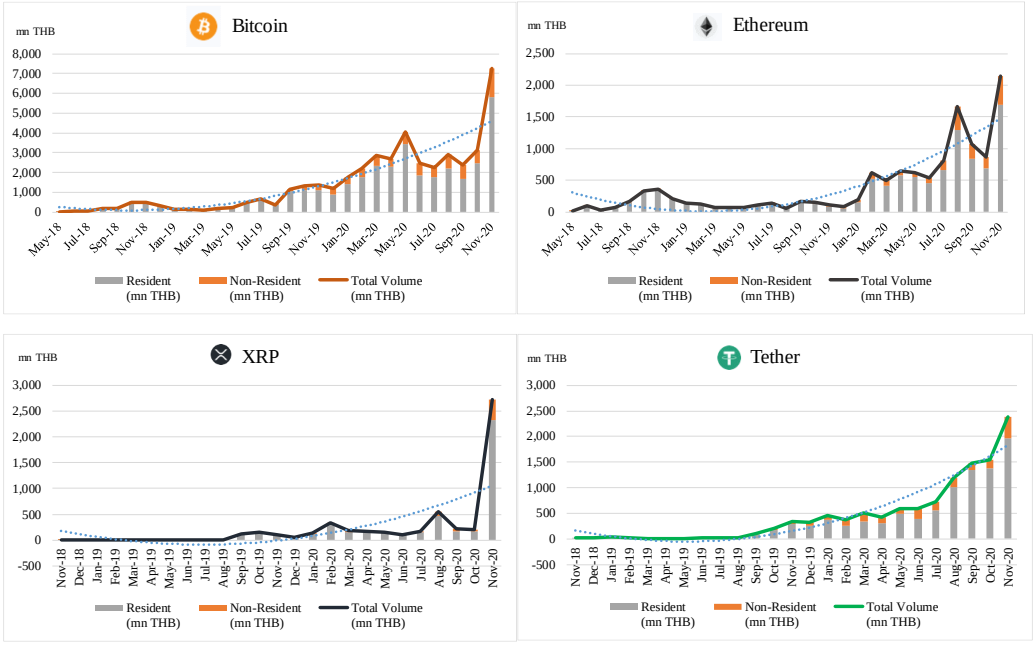
Figure 1 Penetration rates of the leading social networks in Thailand, January 2021



Source: Statista (2021)

Second, cryptocurrencies were popularly received in Thailand. Thais rank second in terms of global cryptocurrency ownership (Wearesocial, 2019). Trading volumes of some cryptocurrencies and stablecoins at Bitkub — one of the largest Thai crypto exchanges in terms of national trading volume — exhibited rapid growth in 2020 (Figure 2). Adoption is expected to continue expanding, especially if cryptocurrencies could transform themselves from speculative assets to become widely accepted as a medium of exchange or a reliable unit of account.

Figure 2 Monthly trading volume of top 4 cryptocurrencies and stablecoins at Bitkub, one of the largest Thai crypto exchanges



Data coverage: since the inception of Bitkub or the first day of each crypto trade until the end of November 2020
Source: Bitkub, calculated by authors

The Bank of Thailand (BOT) should understand the implications of the changing financial landscape arising from the advent of private-issued and foreign digital currencies, which will alter the way consumers and businesses transact with one another. These understandings will help the BOT to stand ready for the unforeseeable future and issue retail CBDC should the demand for better public money arises. Retail CBDC would enable the national monetary and payment systems to benefit from higher efficiency, more equitable access, and more inclusive opportunities.

This paper aims to highlight key monetary and financial perspectives on retail CBDC in the Thai context. In Part 2, the role of public money in the digital age is discussed. The attractiveness of retail CBDC is compared with other alternatives, and the potential for retail CBDC adoption is projected. In Part 3, the implications of retail CBDC for monetary policy and the central bank's balance sheet are addressed. Part 4 then examines potential risks of issuing retail CBDC on the banking system together with the mitigation of those risks.

2. Public money in a changing financial landscape

In the current monetary system, the central bank plays a key role in providing money as a core public good for the economy. Money is used as the ultimate safe medium to settle wholesale and retail transactions. Meanwhile, commercial banks and other private sector play the role of innovating on retail payment instruments to serve public need.

Given the rise of financial innovation that could reshape the future financial and payment landscape, it is possible for public money and public infrastructures to better serve the experience of money users. Digital public money could deliver financial services that have easier access, lower costs, and higher quality, as well as greater interoperability among private sector intermediaries. This would ensure that a trusted and safe means of payment remains accessible to households and businesses in the digital age, and it would co-exist with cash and other payment instruments. In addition, owing to potential currency competition by other digital currencies, there is a scope for digital public money to safeguard monetary stability and maintain the effectiveness of monetary policy transmission to the economy. Although currency competition is not currently a key concern in Thailand, it warrants continuous monitoring.

To gauge potential public demand for retail CBDC, the attractiveness of retail CBDC for the money user is compared with other payment alternatives, and a potential path of adoption for retail CBDC in Thailand is projected. Our analysis shows that unremunerated CBDC is the most attractive substitute for cash with potentially high adoption rate within a decade, assuming that other digital currencies have not yet been widely accepted in domestic activities to benefit from network effects.

2.1 The role of public money in the digital age

In the current setting of the dual monetary system, public and private money co-exist. The central bank issues public money. These include physical cash (banknotes and coins) which are accessible to all, and electronic deposits at the central bank (bank reserves or settlement balances) which are only accessible to qualifying financial institutions. Public money are liabilities of the central bank with exceptionally low risks, upholding the stability and efficiency of the monetary system. Meanwhile, private money build on the foundation of public money but are direct claims on private money issuers rather than the central bank. While private money provide innovation and product diversity, their holders may also be exposed to some default risks. Examples include bank deposits, electronic cards, and e-money in e-wallets, as well as other financial products provided by banks and payment providers.

If the monetary system depends too much on either type of money, trade-offs could arise (Adrian & Mancini-Griffoli, 2021). Prevalence of public money could lead to the lack of financial innovations, whereas too much reliance on private money could pose risks. Therefore, public and private money co-exist and reinforce each other. For example, the central bank supports private money in several ways such as (i) allowing commercial banks to settle interbank payments using central bank money, (ii) allowing the general public to convert

between commercial and central bank money through banknote provision, and (iii) offering contingent liquidity through the lender of last resort function (Boar, et al., 2020).

In the digital age, the fintech revolution has changed the nature of money into a new form—digital currencies, fostering more efficient form of money. Digital currencies can now facilitate instant peer-to-peer transfers with low costs that were previously impossible, especially for cross-border payments, creating new opportunities for both public and private money. Private-issued stablecoins, regarded as a kind of digital currencies, can offer benefits of stable price, low costs, high speed, and seamless payments with blockchain-based assets. These private digital currencies may potentially become alternative means of payment by scalability through non-banks' network platforms. This issue leads to a question of public role in providing more innovative, convenient, and user-friendly money to serve rapidly evolving user needs. A retail CBDC, which in practice is a digital form of cash, would retain the properties of existing public money, including the legal tender status and being a direct claim on the central bank. This new form of public money would reshape the monetary system by providing an accessible, reliable, and safe option of digital currency for citizens, laying out the groundwork for a safe payment infrastructure, as well as building interoperability and collaboration with the private sector to embrace financial innovation (Bank of Thailand, 2021).

2.2 Benefits of digital public money

Apart from providing an efficient form of public money in the digital age as mentioned, there are some other issues for the central bank to consider in issuing its own retail CBDC. In particular, if private-issued or foreign digital currencies are at risk of being continuously adopted in the country, these currencies could become systemically important at the expense of sovereign currency and national authority. **Some costs of non-sovereign digital currencies are described below.**

(a) Weakened monetary sovereignty and financial stability: presently, the credibility and integrity of the Thai monetary system remain robust. The Thai baht is used pervasively as the unit of account in the economy. However, there is a future risk that sovereign currency could be supplanted by alternative digital currencies, which is known as "digital dollarization" (Brunnermeier, et al., 2019). If this point is about to be reached, there is an imperative to issue retail CBDC. Without retail CBDC, prices and contracts could be set using non-sovereign denominations. Economic activities would center around the non-bank platforms of currency issuers rather than domestic banking system. The central bank, whose mandates include preserving monetary and financial stability, would face challenges in managing the money supply, transmitting monetary policy tools to stabilize the economy according to domestic business cycles or credit cycles, and acting as the lender of last resort in the financial system (Chucherd et al., 2019). Instead, the economy would be subject to the currency issuers' policies, be they foreign governments or transnational corporations, who may not always act in the best interest of the domestic economy. Monetary and financial stability would therefore be weakened (G7 Working Group on Stablecoins, 2019; Rios & Zhu, 2020). By contrast, retail CBDC may ensure that the monetary system remains centered around the

national jurisdiction, and if remunerated may even lead to enhanced monetary policy effectiveness as discussed in detail in Part 3.

(b) Problems associated with monopolistic behavior: payment services tend toward natural monopolies due to strong network externalities, the economies of scale, and the gains from using data to provide additional services (Gowrisankaran & Stavins, 2004; Bolt & Humphrey, 2005). It is possible that large private payment firms could offer partial, inadequate or expensive services. For example, individual currencies could be specialized so that they cannot be used across all platforms, leading to a fragmented monetary system. Monopolies may not adequately internalize some social costs, such as the costs of underinvesting in cybersecurity, leading to economic disruptions when the risks become manifest (Kiff, et al., 2020). By contrast, central bank-issued digital public money would be a public good that is open and interoperable across platforms (Brunnermeier, et al., 2019). This will promote efficiency and innovation, allowing more firms to build financial services on a level playing field due to the lower barriers to entry. The social costs of public money provision would be absorbed by the central bank to ensure systemic stability (Table 1).

Table 1 Costs associated with the development and operation of retail CBDC[7]

Cost category	Examples
Labor	IT consulting firm, developers, user experience specialist; wallet maintenance costs
Infrastructure	cloud or on-premise servers
Software	licenses, service fees
Cyber Security	threat modeling, protection, identification, response management, penetration tests
Support	help desk, training, communication

Source: Kiff et al., 2020

In addition to the two issues described above, **retail CBDC may have other advantages** in itself as listed below (Boar, et al., 2020; Kiff, et al., 2020).

(c) Reduction in the size of gray and black market activities: if retail CBDC becomes widely adopted, the use of cash would be reduced while a new data trail of transactions would become available for the central bank (Auer, et al., 2020). Gray or black market activities[8] that depend on the storage of cash would be reduced in size. Participants would be forced to exit the market or become formalized (Agarwal & Kimball, 2015). This is a relevant motive in Thailand where the gray and black market activities accounted for more than 60-70% of GDP during 1999-2004 (Bunjerdkit, 2007). The size black market in Thailand, estimated to be 13% of GDP (Havoscope, 2012), are dominated by gambling, human trafficking, and drugs.

[7] These costs have not included environmental impact. If retail CBDC is operated on the distributed ledger technology, similar to cryptocurrencies and stablecoins, it would require high computing power from different nodes (Ward & Rochemont, 2019).

[8] This paper defines "gray market economy" based on the International Labor Organization (ILO) definition as a section of economy of which labor is not protected under labor protection law. Meanwhile, "black market economy" is a section of economy that is illegal.

(d) Higher effectiveness and efficiency of government transfers: the public sector could use the data related to retail CBDC transactions to understand real-time and micro-level economic developments, leading to more effective public policies that are targeted to those in need**.** Moreover, the technology of retail CBDC itself could become a powerful payment rail for stimulus and other government-to-person **(**G2P**)** transfers, helping to accelerate disbursements and program rollouts, such as by building on smart contracts**.**

(e) Higher efficiency compared with cash: retail CBDC would have lower cost per transaction than cash. The more CBDC is widely adopted, the lower the marginal costs of cash issuance and management (Kiff, et al., 2020). Nonetheless, this will also partly depend on whether fixed costs of cash would decline, and the fixed costs associated with setting up CBDC.

2.3 Public demand for retail CBDC

To gauge how much retail CBDC may be demanded by the public, this section compares retail CBDC with other forms of money, namely, cash, e-money, bank deposits, and stablecoins. We apply the IMF conceptual framework (Mancini-Griffoli, et al., 2018) to the Thai context where the demand for a specific means of payment is determined by the individual's perception of its comparative benefits, transaction costs, and risks. This paper adds one special feature to the IMF criteria for the Thai context, namely, protection under the Criminal Code. Each criterion receives a performance score between 0 to 3, as shown in Table 2. The results are summarized on a spider web chart, with larger areas reflecting higher total scores. Full detail of each product's scoring is described in Appendix I.

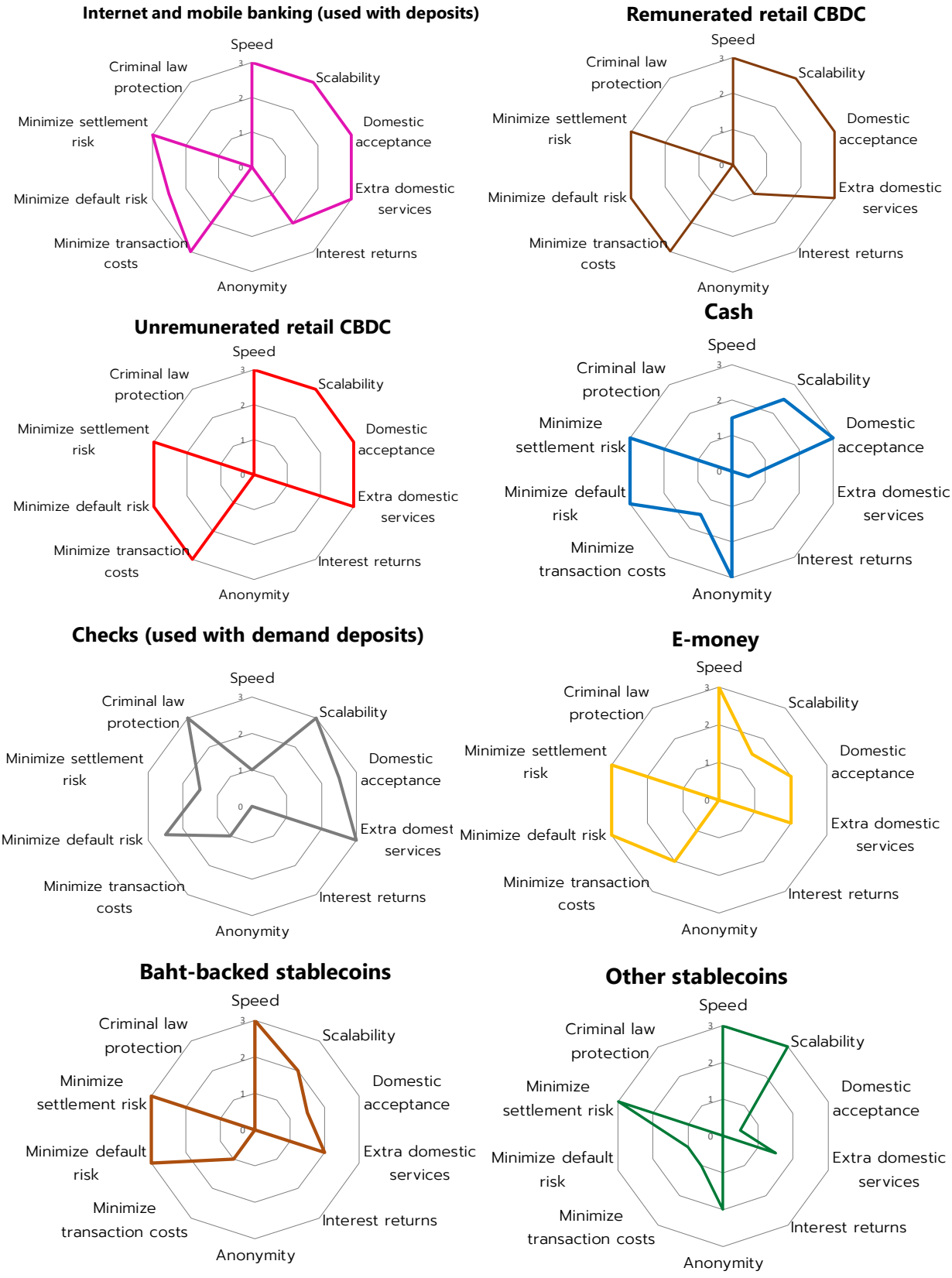
Table 2 Scoring criteria from users' perspective on holding money

	Criteria
Maximize benefits	▪ **Speed:** time required to complete transaction *[score: 3 = fast; 0 = slow]* ▪ **Scalability:** payment of any size (no limits) *[score: 3 = for all amount/transaction; 1 = for very small amount/transaction]* ▪ **Extra domestic services:** access to financial services (e.g. loans, financial advice), sales promotion *[score: 3 = variety of extra services; 0 = no extra service]* ▪ **Domestic acceptance:** person to person, business to people, business to business, to and from any device, no network limitation *[score: 3 = widely accepted; 0 = not accepted]* ▪ **Interest returns:** *[score: 3 = high interest rate return; 0 = no interest rate return]* ▪ **Anonymity*:*** *[Score: 3= full anonymity; 0 = no anonymity]*
Minimize costs	▪ **Transaction costs:** *[score: 3 = very small transaction costs; 0 = high transaction costs]*
Minimize risks	▪ **Settlement risk:** lag between agreeing to a transaction and actual receipt of funds *[score: 3 = almost risk free; 0 = very high settlement risk]* ▪ **Default risk of the money issuer:** *[score: 3 = almost risk free; 0 = very default settlement risk]* ▪ **Criminal law protection*:*** default on payment is a criminal offense *[score: 3 = present; 0 = absent]*

Source: adapted from Mancini-Griffoli et al. (2018)

Retail CBDC is compared with cash, e-money, checks used with demand deposits, and stablecoins. The scoring for each are shown on Figure 3 and Figure 4.

Figure 3 Spiderweb scores of different means of payment by criteria



Source: adapted from Mancini-Griffoli et al. (2018), scoring by authors

Figure 4 Summary scores of different means of payments

	Total Scores
Internet and mobile banking (used with deposits)	22.5
Remunerated retail CBDC	22.0
Unremunerated retail CBDC	21.0
Cash	18.0
Checks (used with demand deposits)	17.5
E-money	16.5
Baht-backed stablecoins	15.5
Other stablecoins	15.0

Source: adapted from Mancini-Griffoli et al. (2018), scoring by authors

The scoring shows that internet and mobile banking used with bank deposits are the most attractive means of payment, followed closely by retail CBDC, both remunerated and unremunerated respectively. All three offer fast payments, low transaction costs, low risks, have widespread acceptance, and can be used to access various domestic services. In particular, bank deposits offer competitive returns that make them the most attractive means of payment. **Cash is ranked fourth with high score in several aspects,** including high degree of anonymity, widespread acceptance, and low risks. **Checks used with demand deposits are ranked fifth** owing to the slow speed of check processing as well as potential default and settlement risks. Nonetheless, check bouncing remains a criminal offense in Thailand, helping to reduce transaction risks. **E-money is ranked sixth** due to less widespread acceptance and lower scalability. **Stablecoins, both baht-backed and other types, are assessed to be least attractive for consumers** with low scores on multiple aspects, especially limited domestic acceptance and high transaction costs.

From the scoring assessment above, we expect that retail CBDC, cash, e-money, checks, and internet and mobile banking, would co-exist under the future payments landscape in Thailand. Retail CBDC has a high potential to substitute much of the present cash usage, albeit not completely. Retail CBDC may also gain some share from e-money given higher relative benefits of CBDC including wider acceptability, higher convenience from CBDC interoperability, and greater access to future digital financial services.

If unremunerated retail CBDC is issued, it would substitute cash use and its upper limit would be the present level of currency in circulation, equal to 9.4% of Thailand's GDP in 2019 (Figure 5). **The actual path of retail CBDC adoption could be somewhere in the range under the upper limit**, depending on users who persist in using cash, such that those that prefer cash over electronic payments[9], those in remote areas lacking smartphone or internet access[10], and participants in the gray and black market activities. Regarding the speed of retail CBDC adoption, Bass (1969)'s model of technology diffusion[11] is used for projection. It is assumed that the speed of retail CBDC adoption would closely mirror e-money in Thailand over the period 2010–2020. **Retail CBDC adoption would gradually increase and begin**

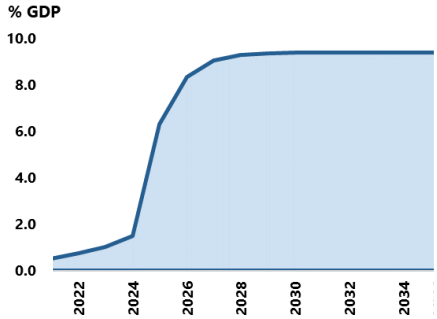
[9] Reasons that some households voluntarily exclude themselves from financial services included poor financial positions, insufficient incomes, lack of understanding about financial services, lack of confidence about contacting banks, and concerns over transaction costs (Moenjak, et al., 2019).

[10] However, if retail CBDC has an offline functionality, this could attract users in remote areas, leading to higher adoption.

[11] Described in Appendix II

stabilizing within a decade, assuming that overall money demand grows at the same rate as nominal GDP.

Figure 5 Projected path of unremunerated retail CBDC in Thailand if it completely replaces currency in circulation



Source: Authors' projection

Nevertheless, our results are sensitive to fluctuations in money demand. On the one hand, *the speed of retail CBDC adoption could be quicker than projected*. Digital financial infrastructure in Thailand is now better established and users are more familiar with financial innovation than during the period 2010–2020. Banknote usage may be discouraged by potentially recurring COVID-19 outbreaks or by government promotion of retail CBDC through fiscal transfers. Moreover, *adoption could exceed the estimated upper limit* if further technological developments increase the benefits of both wholesale and retail CBDC, substituting not only cash but also other electronic payments. On the other hand, *the speed of retail CBDC adoption could be slower than projected,* for example, if policy rate normalization raises the opportunity cost of holding non-remunerated assets like CBDC. *Adoption could be significantly lower than the estimated upper limit* if those persisting with cash dominate transactions, or if future financial innovations and alternative currencies gain the share of users while bypassing the BOT's retail CBDC infrastructure. Therefore, consumer demand for different types of money will be the key determinant of retail CBDC adoption.

3. Implications on monetary policy

The introduction of retail CBDC has the primary purpose of maximizing and enhancing the effectiveness of CBDC in performing its role of money, namely costless medium of exchange, secure store of value, and stable unit of account (Bordo & Levin, 2017). Nonetheless, thanks to the technology behind its issuance, introducing CBDC could offer opportunities in other dimensions, apart from benefits aforementioned, including the possibility of enhancing the monetary policy effectiveness (Barrdear & Kumhof, 2016; Armelius, et al., 2018)

However, the benefits would only be realized once retail CBDC has been widely used in place of cash, otherwise it would end up adding costs to the economy (Davoodalhosseini, 2018). The model results from the second part suggest that it could take approximately a decade for retail CBDC to be widely adopted unless there were government

support or other accelerating factors. Meanwhile, promoting financial and digital literacy should also be done in tandem to foster a digital-friendly environment and ensure better financial inclusion.

This part discusses implications of introducing retail CBDC to the monetary policy. The degrees of impacts would depend crucially on how they are distributed and whether they are remunerated. Regarding distribution, this study assumes that retail CBDC is supplied to the general public on demand via commercial banks as intermediaries (two-tiered distribution). It means that to obtain retail CBDC, individual has to open a CBDC wallet with commercial banks who will then exchange either cash or deposits in return for CBDC with the central bank. The central bank only plays a role as issuer of retail CBDC and not as a distributor. For remuneration, there are two types of retail CBDC in this study. Remunerated CBDC is retail CBDC that pays interest, whereas non-remunerated CBDC does not pay any interest.

Overall, the study finds that introducing remunerated CBDC could help improve the pass-through of the existing monetary policy tool given the appropriate CBDC rate as well as offer new monetary policy tool. However, it would have an impact on balance sheets of both commercial bank and central bank, as well as central bank's revenue. We explore potential pre-emptive measures to reduce potential impacts in the next part.

3.1 Implications on the monetary policy transmission

This section explores implications of one of the important design features of retail CBDC which is remuneration. Many central banks have explored remunerated CBDC and found that the introduction could influence other market interest rates and complicate the monetary policy transmission. Degree of implications, however, vary with the level of interest paid and corresponding response of banks. Therefore, identifying the appropriate interest rate is crucial and in this section, we explore the appropriate level of interest rate on retail CBDC which could enhance understanding on the impacts on monetary policy transmission.

<u>The appropriate level of interest rate on retail CBDC</u>

The interest rate paid on retail CBDC, or CBDC rate thereafter, could be calculated by comparing properties of retail CBDC with those of other financial assets. **Returns on retail CBDC, like other financial assets, should depend on properties including risks of devaluation, transactional utility, and other benefits from holding the asset.** We compare these properties with those of other financial assets to find the appropriate level of CBDC rate. First, risks of devaluation could arise due to default, liquidity and interest rate risks, as well as cyber risk. Second, transactional utility arises from the convenience received from holding assets that can be used for transaction purpose. Third, other benefits come from extra financial services offered by issuers of financial assets such as credit provision from holding deposits with commercial banks or discounts from holding money in e-money wallet.

Comparing with a risk-free asset, CBDC holds a cash-like property. CBDC thus has no default risk as it has a direct claim on central bank and is also free from liquidity and interest rate risks. As a result, CBDC has no risk of devaluation and CBDC rate should be consistent

with return on risk-free asset like short-term government bond which is close to the policy rate. Nevertheless, given that CBDC provides transactional utility, CBDC rate should thus be lower than risk-free rate and equal risk-free rate minus a premium earned from such transactional utility. **This implies that CBDC rate is lower than policy rate.**

$$i_t^{CBDC} = i_t^f - \emptyset_t^{CBDC}$$

Comparing with deposits, CBDC provides similar transactional utility. However, holders of deposits are often offered extra financial services such as credit provision, whereas holding CBDC provides no extra financial services but offers other benefits such as security. Therefore, CBDC rate should then equal deposit rate plus a premium, which can be either negative or positive, **depending on relative convenience yield from holding deposits versus holding CBDC ($\emptyset_t^d$)[12]. This implies a spread between** i_t^{CBDC} and i_t^d ($i_t^{CBDC} - i_t^d$).

In reality, relative convenience yields vary across individuals, while deposit rates are set separately by banks. Therefore, people make different decisions to hold deposits or CBDC based on whether the relative convenience yields are higher or lower than the spread between CBDC and deposit rates ($i_t^{CBDC} - i_t^d$).

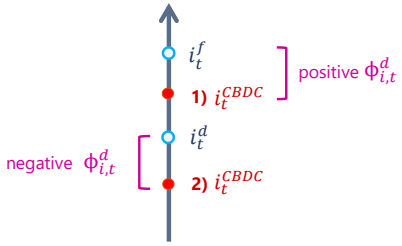
$i_t^{CBDC} - i_t^d = \emptyset_{i,t}^d$ An individual is indifferent between holding deposits and CBDC.

$i_t^{CBDC} - i_t^d > \emptyset_{i,t}^d$ An individual prefers holding CBDC to deposits.

$i_t^{CBDC} - i_t^d < \emptyset_{i,t}^d$ otherwise

In response to decisions of individuals, banks can then determine deposit rates according to the relative convenience yield and their target level of deposits (Figure 6 and more detail in Appendix III).

Figure 6 Appropriate level of CBDC rate



Source: Authors

<u>The impact of remunerated CBDC on transmission through bank channel</u>

The effectiveness of monetary policy transmission is measured by how the change in policy rate can influence other interest rates in the financial markets, in which changing funding costs are consequently passed on to the economy at large. In this section, we will focus on the first part on how CBDC rate influences commercial bank interest rates, especially deposit and lending rates. This could largely represent the impact on the overall

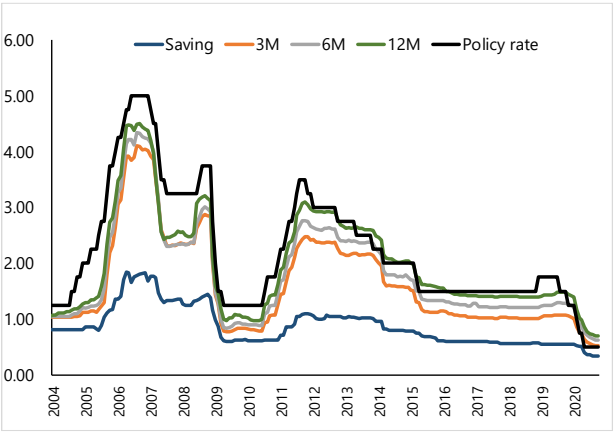
[12] The relative convenience yield depends on how people weigh costs and benefits from holding deposits versus holding CBDCs.

economy as Thailand is a bank-based economy where more than 70 percent of businesses raise funds through bank credits.

A. Transmission to deposit rates

In general, **the pass-through from the change in policy rate to deposit rates was observed to be less than one-to-one which means that the change in the policy rate is not fully transmitted to deposit rates.** In this section, we explore whether there is any potential for improvement in the transmission.

Figure 7 Movements of bank deposit rates and the policy rate



Source: Bank of Thailand

In the case of Thailand, the pass-through from the policy rates to deposit rates has been lower than one-to-one. An increase in the policy rate by one percentage point causes effective deposit rate (EDR) to increase, on average, by only 0.44 percentage points (Table 3). In particular, saving, 3-month, 6-month and 12-month time deposit rates rose by only 0.28, 0.78, 0.79 and 0.78 percentage points, respectively.

Table 3 Sensitivities of different deposit rates to the policy rate

Variables	Effective deposit rate	Saving	3-month	6-month	12-month
Policy Rate	**0.441*** **	**0.281*** **	**0.774*** **	**0.794*** **	**0.778*** **
	(0.0358)	(0.0217)	(0.0203)	(0.0244)	(0.0270)
Constant	**0.848*** **	**0.369*** **	**0.146*** **	**0.309*** **	**0.624*** **
	(0.0897)	(0.0522)	(0.0487)	(0.0587)	(0.0650)
No. of observations	66	238	238	238	238
R-squared	0.704	0.414	0.861	0.817	0.778

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Bank of Thailand, authors' calculations

The introduction of remunerated CBDC may help improve the monetary policy transmission to deposit rates, but the extent of such improvement will largely depend on (1) potential deposit adjustments resulting from a change in the policy rate, and (2) banks' target levels of deposits. An expected improvement could therefore be ambiguous. Moreover, as remunerated CBDC and deposits have similar features as mentioned

in Part 1, remunerated CBDC will be a direct competitor to deposits, potentially raising competition in the banking industry. When central bank adjusts the policy rate, banks that wish to maintain deposit levels will have to adjust deposit rate to remain attractive, thereby improving transmission to deposit rates.

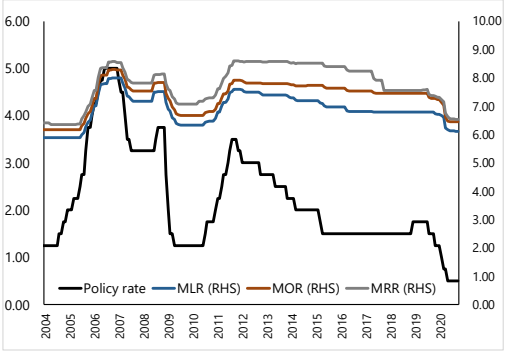
In an extreme case, Armelius et al. (2018) found that the full pass-through to deposit rates could be achieved if CBDC rate is set at the appropriate level corresponding to a change in the policy rate. In the case where convenience yields from holding retail CBDC and deposits are homogenous, banks are then forced to adjust deposit rates to maintain the spread between deposit and CBDC rates or risk losing deposits.

Nevertheless, as mentioned in an earlier part, convenience yields from holding retail CBDC and deposits across individuals are actually heterogeneous. Given the imperfect pass-through to deposit rates, a policy rate cut and corresponding change in CBDC rate will narrow the spread between CBDC and deposit rates. This induces some CBDC holders to switch to deposits as relative convenience yield becomes larger than the spread. On the other hand, an increase in the policy rate will result in a wider spread between CBDC and deposit rates. Thereby, some depositors could switch their deposits to CBDC as relative convenience yield becomes less than the spread (more detail in Appendix IV). If the pass-through remains the same, banks are likely to lose some but not all deposits as banks will likely respond to the policy rate change in varying degrees across different type of deposits as aforementioned. In this case, banks' decisions to adjust deposit rates further will therefore depend on potential deposit adjustments and target levels of deposits. Hence, improvement in the pass-through could be limited as large deposit inflows or outflows may not be extreme.

B. Transmission to lending rates

In the case of Thailand, pass-through from policy rate to lending rates is also observed to be less than one-to-one as seen in Figure 8. According to regression result (Table 4), the pass-through from policy rate to effective lending rate (ELR) is 0.43. Meanwhile, considering the new loan rate (NLR), which is the actual lending rate that commercial banks charge on new loans, the pass-through is higher (0.79) but is still less than one-to-one (Amatyakul, et al., 2019)

Figure 8 Movements of bank lending rates and the policy rate



Source: Bank of Thailand

Table 4 Sensitivities of the effective lending rate to the policy rate

VARIABLES	Effective Lending Rate
Policy Rate (RP)	0.430***
	(0.033)
Exogenous Deposit Rate	0.901***
	(0.115)
BOT's Leading Economic Index (YoY)	2.419
	(1.534)
Constant	4.366***
	(0.0955)
No. of observations	66
R-squared	0.792

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Exogenous Deposit Rate is a residual of $i_t^d = \beta_t^{(0)} + \beta_t^{(1)} RP_t + u_t$

Source: Bank of Thailand, authors' calculations

Given the assumption that deposit and lending rates are not set separately but with some degree of relationship between these two bank rates, introduction of remunerated CBDC may help improve the pass-through to lending rates in a similar manner. Armelius et al. (2018), however, found that the introduction of CBDC would not improve the lending rate pass-through in the case where there are no joint variable costs[13] between deposit and lending and that lending and deposit rates are set separately in response to change in the policy rate. Improvement in deposit rate pass-through therefore has no effect on pass-through to lending rate. However, as can be seen in the Thai case (Table 4), the regression result suggests a presence of joint variable costs, since an exogenous change in the deposit rate contributes to a change in ELR by almost the same degree (the coefficient is 0.90). This implies that a change in deposit rate caused by a change in the spread between CBDC and deposit rates could result in a change in lending rate by almost the same degree.

Overall, the introduction of retail CBDC could help improve the pass-through from policy rate to both deposit and lending rates provided that retail CBDC pay appropriate level of interest rate. However, the extent of improvement is subject to banks' willingness to adjust interest rates in response to potential deposit adjustment and their target level of deposits. This may result limited improvement in the pass-through.

Although there are potential benefits from issuing remunerated CBDC in improving bank rate transmission, it should be carefully weighed against potential costs on bank lending. As people could switch from holding deposits to retail CBDC at any time, deposit-funded banks may potentially face difficulties in providing loans. As a result, deposit rates may rise to attract deposits, if banks need them to make loans (more detail in appendix IV), making lending more expensive. However, if banks do not need to retain the funding lost to retail CBDC, they may not raise deposit rates as explained in Part 4. Hence, the impact of

[13] Joint variables costs occur when banks jointly offer deposits and loans, and are thus subject to joint managing costs (Armelius et al., 2018). According to Clark (1988), one of the sources of variable costs is information. For example, information from deposit transactions help improve credit risk assessment, therefore lowers cost of bank lending.

retail CBDC on the ability of banks to provide lending and net impacts on overall economy should be kept in mind.

3.2 Implications on central bank balance sheet and monetary operations

Implication of CBDC issuances on central bank's balance sheet is another dimension of impacts that is of interest to many central banks (Kumhof & Noone, 2018; Nessén, et al., 2018; Bindseil, 2020). The added features that retail CBDC could offer, including remuneration, could make holding CBDC relatively more attractive than cash or deposits. In particular, if demand to exchange deposits for retail CBDC continues to increase, this will raise concern on the shift from broad money to monetary base, potentially inflating the size of central bank's balance sheets and complicating monetary operations. In this case, central bank may have to rethink whether adjustment to the current monetary policy implementation framework will be needed.

In this section, **we explore the implications that could arise from issuing retail CBDC in three cases: (1) non-remunerated CBDC, (2) remunerated CBDC, and (3) CBDC as a new monetary policy tool.** For the first two cases, we study implications of issuing retail CBDC by considering any possible movements of assets and liabilities across balance sheets of three key economic agents, namely households and firms, commercial banks, and central bank, in order to observe the impact of issuing CBDCs on each agent (Kumhof & Noone, 2018; Bindseil, 2020; Gross & Siebenbrunner, 2019). Table 5 below illustrates the simplified version of balance sheets of each economic agent.

Table 5 Balance sheets of economic agents

Central bank		Commercial bank		Households and firms	
Asset	Liabilities	Asset	Liabilities	Asset	Liabilities
Foreign reserves	Bank reserves	Bank reserves	Deposits	Deposits	Loans
	CIC	CIC			
Domestic assets	Other items incl. OMOs	Loans	Other liabilities	Other assets	
		Other assets	Equity	CIC	Equity

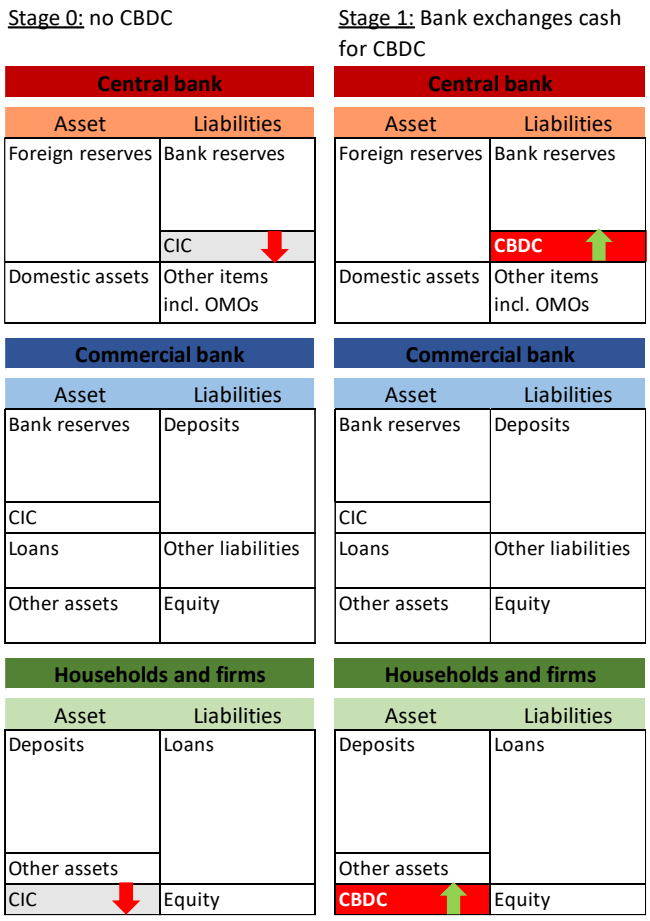
Note: Currency in circulation (CIC) includes both banknotes and coins in circulation

Similar to the study of Kumhof and Noone (2018), we assume that liquidity demand of each sector remains unchanged so an increase in CBDC holding must be offset by a fall in either cash or deposits by the same magnitude. We also assume that retail CBDCs can only be used for payment and settlement purposes and not for investment, and that banks cannot hold retail CBDCs as part of its required reserves. We also assume that non-remunerated CBDC can only be exchanged with cash, while remunerated CBDC can only be exchanged with deposits. However, in practice, this may not be the case as private sector will optimize its holding of each of the three assets.

Case 1: non-remunerated CBDC

In the first case, retail CBDC is designed to have a cash-like property, including non-remuneration, and are supplied on demand. Thus, retail CBDC in this case is considered as monetary base. In the corridor system, central bank has to maintain the level of bank reserves to ensure that short-term rates in the money market move in line with the policy rate. **Introducing CBDC seems to have little implications on monetary operations of central banks as it only induces a switch from CIC to CBDC holding. Level of monetary base and overall bank reserve level remain unaffected.** However, implications may arise regarding liquidity demand forecast. Retail CBDC, as another type of cash, will be considered as autonomous factor when forecasting liquidity (Riksbank, 2017). With increasing popularity of retail CBDC, forecasting demand for retail CBDC can be challenging in the short run as demand can highly fluctuate resulting from volatile flows of funds in and out of retail CBDC accounts (Bank for International Settlements, 2018). Nevertheless, in the longer run, with greater adoption of retail CBDC, forecasting could be enhanced as the usage of CBDC is traceable.

Table 6 Exchanging cash for unremunerated retail CBDC



In Table 6 above, stage 0 is when retail CBDC is not yet introduced to the economy. In stage 1 when retail CBDC is introduced and households and firms demand CBDC due to higher transactional utility than cash. Assuming that private sector can only exchange cash for CBDC, CICs of households and firms then fall while retail CBDC rises**. At the same time, central bank**

will see a change in the composition with CBDC balance on the liability side in place of CICs, where the size of its balance sheet is unaffected. Commercial bank, however, will not be affected in this case as the private sector holds CBDC wallet which has a direct claim to the central bank.

Case 2: remunerated CBDC

In the case where retail CBDC is remunerated like bank deposits, appropriate CBDC rate needs to be considered when implementing monetary policy as discussed earlier. Demand for remunerated CBDC is expected to increase if the spread between CBDC and deposit rates is higher than relative convenience yield from holding deposits over CBDC, and given rising attractiveness of holding CBDCs as alternative choice of risk-free investment. A shift from deposit holding results in a switch from broad money to monetary base. This could raise concerns regarding bank disintermediation and massive bank runs especially in time of crisis. The extent of the impact will be discussed further in the next part.

Assuming that private sector can only exchange deposits for CBDC, the private sector then exchanges deposits for remunerated CBDC as seen in Table 5. In stage 1, private sector exchanges half of its deposits for retail CBDC. This effects the composition of balance sheet, increasing the amount of CBDC on the asset side while reducing deposits by the same magnitude. **Consequently, commercial bank will run down both bank reserves and deposits at the same time, shrinking the size of its balance sheet. Meanwhile, central bank will find lower bank reserves with an increase in CBDC on its liabilities.**

Nonetheless, in an extreme case where banks do not respond by changing deposit rates (stage 2 of Table 7), the private sector could demand more CBDC and wish to exchange all of deposits at commercial bank. **Commercial bank will have to deplete more of its bank reserves in exchange for CBDC. This shrinks balance sheet of commercial bank further. Meanwhile, central bank will find more CBDC on its liabilities alongside depleting bank reserves.** However, in practice, commercial banks are obliged to maintain a minimum amount of bank reserves with the central bank. Such reserve requirement (RR) is a fraction of commercial banks' liabilities including, for example, deposits or other highly liquid assets that can be easily liquidated. In the case of Thailand, since July 2016, RR was set at 1% of deposits and borrowings.

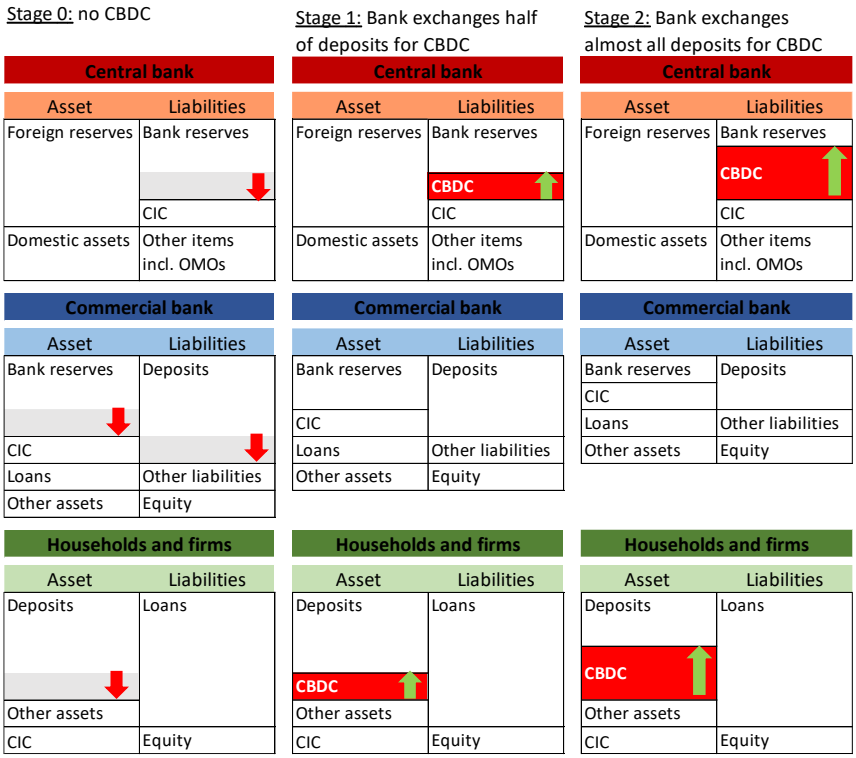
With rising demand for remunerated CBDC, central bank will observe continuing shift from broad money to monetary base which could undermine monetary policy transmission via banks. Meanwhile, commercial banks will face challenges in accommodating rising demand for CBDC while also having to obtain liquidity to fulfil its obligation in maintaining required reserves with the central bank.

Commercial banks can end up in liquidity-deficit positions and may choose to react according to the following options. First, banks may choose to liquidate their assets in exchange for CBDC. Second, banks can choose to find alternative source of funding including borrowing from the interbank market or from central bank via intraday credit facilities. Should there be a massive and one-side demand to borrow, this could drive up lending facility's interest rate to the ceiling of its corridor. Subsequently, if banks cannot

borrow among themselves, banks will have to borrow from central bank via bilateral repurchase operation in order to return the intraday credit. As a result, this process could cause market rates to be misaligned with the policy rate (Bank of England, 2020).

However, banks' decisions whether to deplete bank reserves, liquidate assets, or find alternative sources of funding would depend on relative costs of different options (Kumhof & Noone, 2018) as well as their strategies in maintaining short-term and long-term funding stability (Juks, 2018). For other options, the availability of eligible collaterals will limit the ability to borrow from central bank. **Central bank thus needs to rethink whether adjustments to its monetary policy implementation framework is necessary in response to potential bank disintermediation and impact on monetary policy transmission.** Nonetheless, the transition toward a CBDC-based economy will take time and banks' depleting almost all bank reserves for CBDC as the example case is unlikely to happen in the near term.

Table 7 Exchanging deposits for remunerated retail CBDC



It is to note that case 1 and 2 can actually occur simultaneously depending on decisions of individuals to substitute how much cash or deposits for CBDC. In addition, if commercial banks are allowed to hold CBDC as bank reserves, this could have implications on interest rates in the money market. **Setting the appropriate level of CBDC rate is thus crucial. CBDC rate should not exceed policy rate and also deposit rate of deposit facility.** If CBDC rate is higher than those two rates, commercial banks with excess liquidity will not choose to trade excess liquidity in the interbank market or deposit at deposit facilities, but choose to hold CBDC which pays higher return.

Case 3: CBDC as a new monetary policy tool

Another advantage of introducing retail CBDCs includes the possibility to offer new and unconventional monetary policy tool, thanks to the programmable function offered by the new technology (Engert & Fung, 2017; Meaning, et al., 2018). Retail CBDC could be especially designed to meet the need of policymakers in enhancing the effectiveness of the existing tool or offering alternative tools. The problem faced by many countries around the world, especially at the current context of the pandemic crisis, is that existing tools are facing constraints. Policy rates in many countries hit the lower bound. Furthermore, policy rate is a broad-based measure and thus too blunt to address liquidity distribution problem arising from uneven recovery across different economic sectors.

In this light, retail CBDC offers possibilities to address such constraints in two aspects.

First, remunerated CBDC allows for the implementation of negative interest rate policy (NIRP). In the past decade, many central banks, including the Bank of Japan (BOJ) and the European Central Bank (ECB), adopted the NIRP at corporate level aiming to encourage banks to distribute liquidity to the private sector in order to boost the economy and inflation. In theory, issuance of cash which pays zero return acts as a floor for policy rate at zero lower bound (ZLB) as people could move away from holding deposits that pay negative return to holding cash that pays nothing. However, Agarwal and Kimball (2015), as well as Rogoff (2016), suggested that replacing cash with retail CBDC would help eliminate such ZLB, thus allowing the possibility to implement NIRP. However, the effectiveness of the NIRP will be subject to existence of cash. Should cash coexists with retail CBDCs, negative rate will not fully transmit to general public as people can switch to hold cash or deposits instead of retail CBDCs during the negative rate regime.

Second, retail CBDC offers a direct mean to distribute liquidity if retail CBDC is directly distributed to the economy from the central bank. First, quantitative easing measures (QE) could be done through central bank purchases of financial assets directly from market participants while, at the same time, injecting retail CBDC directly to their wallets. This allows a more direct way to reach the target groups, unlike conventional QE where operation has to be done via intermediaries. In that case, central bank cannot control whether liquidity reaches those in need of liquidity. Second, direct transfer of central bank money to wallets of individuals or so-called "helicopter money" could also be done via retail CBDC in order to encourage spending (Dyson and Hodgson, 2016).

However, although the Bank of Thailand Act B.E. 2551 clearly states regarding the central bank independence in conducting monetary policy to ensure growth, price, and financial stability, such direct transfer activities are forbidden in normal times and could blur the line between the roles of monetary and fiscal policies. In addition, in the country where payment system is already efficient, direct transfer of government funds via commercial or state banks can be done with marginal costs. Central bank should thus weigh marginal benefits from implementing such unconventional policy against cost to central bank credibility carefully.

3.3 Implications on central bank seigniorage

In the case where central bank's balance sheet accumulates larger amount of retail CBDC in place of CICs, this could pose threat to the core revenue stream of central bank (Engert and Fung, 2017). On one hand, seigniorage, a revenue earned from banknote issuance, could decline in line with cash usage. On the other hand, introducing retail CBDC could affect seigniorage either positively or negatively depending on two factors: costs of production and net interest expense.

First, the impact depends on degree of cash substitution and the relative costs of producing CBDC versus costs of producing the equivalent amount of cash (Meaning et al., 2018). According to the study of Lamsam et. al (2018), costs related to cash production and distribution was roughly THB 47 billion per year. Despite reduction in cash production costs, issuing CBDC also entails, for example, costs of producing CBDC and maintaining the whole technological system. As more and more people switch to holding CBDC, marginal costs of producing CBDC will gradually decline. As a result, seigniorage is expected to rise in line with degree of cash substitution, provided that CBDC is non-remunerated. However, costs to central bank could be significant if cash and CBDC have to coexist for a long period of time, due to the need to maintain both infrastructures.

Second, the impact depends whether CBDC is remunerated and degree of cash and deposit substitution (Gustafsson & Lagerwall, 2020)**.** In this aspect, the net impact will depend on relative costs of excess liquidity absorption versus costs of CBDC rate.

If CBDC largely replaces cash and CBDC is remunerated, this could reduce seigniorage as there will be cost in paying CBDC interests in addition to costs of excess liquidity absorption in the banking system at the policy rate.

However, if CBDC largely replaces deposits, issuing CBDC may help improve balance sheet of central bank whether it is remunerated or not. As deposits decline, the amount of the excess liquidity in the banking system will be lower. This means that total cost of liquidity absorption will decline. If CBDC is remunerated, CBDC acts as liquidity absorber out of the banking system and thus central bank will have to absorb lower amount of excess liquidity at policy rate. Although central bank has to face both costs of CBDC interests and liquidity absorption at the same time, referring to an earlier finding that CBDC rate should be lower than policy rate, total interest expense should be lower. The cost saved by the central bank will be as below.

$$\text{Net saving cost} = \text{cost of liquidity absorption} - \text{cost of CBDC interest}$$

$$= (i_t^f * \text{excess liquidity}) - (i_t^{CBDC} * \text{CBDC holding})$$

4. Implications on financial institution stability

Retail CBDC may have considerable impact on commercial banks' operations and their stability since we assume that cash, bank deposits and retail CBDC are all interchangeable with each other (Meaning, et al., 2018). Under this two-tiered system, banks are the main distributors of retail CBDC. Banks exchange existing reserves at the central bank for retail CBDC, which are then passed on to customers. The customers may redeem their deposits as cash or as retail CBDC, and may also exchange retail CBDC for deposits.

The literature has identified two main risks for commercial banks arising with retail CBDC issuance. First, disintermediation may occur when retail CBDC crowd out deposits, banks face higher cost of funds, and lending becomes more expensive. The equilibrium amount of credit in the economy may be lower (Kim & Kwon, 2019; Bank of England, 2020; Keister & Sanches, 2020). Second, retail CBDC could exacerbate liquidity problems caused by deposit outflows (Juks, 2018; Kim & Kwon, 2019; Garcia, et al., 2020). Nevertheless, many of these authors assessed that if central banks and commercial banks implemented appropriate adjustments, the risks would be low. As for Thailand, our assessment is summarized in Table 8 below.

Table 8 Expected risks of retail CBDC on the Thai banking system

Unmitigated risks	Scenario	Potential impact	Risk mitigation	Final risks
A. Disintermediation risk		**Very low** impact due to small net deposit outflows		**Very low**
B. Liquidity risk	1. **Normal periods** ***(****High likelihood****)***	**High** impact due to the need to quickly meet CBDC withdrawal requests	*Reduce impact* - **BOT asks banks to prepare sufficient liquidity** for meeting potential outflows	**Very low**
	2. **Distressed periods** e.g. systemic banking sector risks ***(****Low likelihood****)***	**High** impact owing to faster and/or larger deposit runs, leading to large scale asset liquidation and higher financial market volatilities	*Reduce likelihood* - **Appropriately design CBDC from the beginning** o Conversion limits o Multiple-tiered remuneration o Priority for small holders	**Low** if the likelihood can be significantly reduced by CBDC design

Source: Authors' assessment

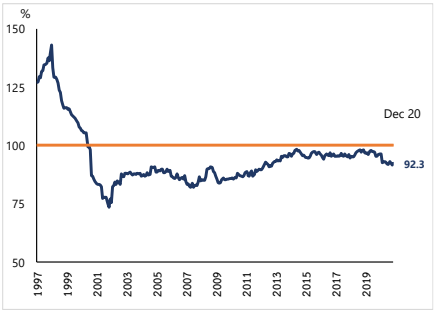
4.1 Disintermediation risk

The risk of disintermediation in a deposit-based economy like Thailand should not be underestimated. At the end of 2020, deposits held by the private non-financial sector represented 71% of total commercial bank liabilities. By contrast, this ratio was only 29% for Sweden (Juks, 2018). Bank funding is thus more vulnerable to deposit losses in Thailand than in market-based economies.

Nevertheless, if deposit losses are confined to a certain level, this may not necessarily impinge lending. Excess liquidity has been a longstanding feature of the Thai

financial system, reflected by the level of deposits that surpassed loans for two decades[14]. At the end of 2020, the loan-to-deposit ratio (LDR) was 92.3% (Figure 9), meaning that deposits needed to fall by 7.7% or by THB 1.18 trillion to be on the same level with loans, all else equal. If CBDC would alleviate the problem of excess liquidity by partially displacing some deposits, banks' costs of deposit funding may, in fact, be reduced.

Figure 9 All commercial banks' loan-to-deposit ratio



Source: Bank of Thailand, excludes interbank items

While it is possible that retail CBDC could continue to grow at the expense of deposits and bank lending, this is unlikely. Even if demand deposits were replaced by CBDC, these represented a small proportion, THB 606 billion in December 2020. Further, should CBDC usage be more widespread than assessed, it is still possible for commercial banks to retain or recover some share lost to CBDC by offering competitive deposit rates[15]. We assess that deposit flows to and from banks in two directions will largely balance out (Table 9), leading to an overall stable stock of deposits in the long run.

Table 9 Motives to hold deposits and retail CBDC

Motives to switch from deposits to CBDC	Motives to maintain deposits and/or switch from CBDC to deposits
1. CBDC could serve some transactions more efficiently than the existing means of payment given its technological superiority, such as linkages with smart contracts or tokenized fundraising.	**4. If necessary, bank rates can rise to ensure that deposits remain attractive,** whichever the CBDC interest rate. This is an important incentive for depositors in the low for long environment.
2. CBDC could be used to hedge against potential deposit defaults, especially since the Deposit Protection Agency (DPA) will protect only up to THB 1 million per financial institution per depositor from August 2021, whereas CBDC could be interpreted as fully guaranteed. However, this motive is likely to be most operational only during high-risk periods. In normal periods, low diversification of saving into CBDC is expected.	**5. Banks could require users to keep deposits in exchange for access to various financial services and consumer experience** such as loans. By contrast, CBDC is a digital representation of cash and not bundled with other services.
3. CBDC could be remunerated and its return may be more attractive than some deposits during some periods.	**6. Likewise, e-money providers could require users to maintain e-money accounts to access their services.** If CBDC users convert to e-money, **this will still lead to deposit inflows** because current payment regulations in Thailand require that all e-money users' amounts be fully deposit-backed[16].

[14] Loans and deposits of the private non-financial sector
[15] As explained in Part 3.1 of this paper
[16] Notification of the BOT. Payment Systems Policy and Financial Technology Group 7/2561 (2018)

4.2 Liquidity risk

Liquidity risks are also concerns for the Thai banking system. In December 2020, 64% of total deposits were held as saving or checkable deposits, which could be redeemed at any time. The equivalent ratio for Canada was 33% (Garcia et al., 2020), so the Bank of Canada's assessment that retail CBDC would not pose liquidity problems for Canadian banks should be treated with some caution in the Thai context. There are risks that deposit withdrawals may substantially increase from the status quo, given lower storage costs, higher speed, and more widespread access of CBDC relative to traditional technologies. If liquidity management is unchanged, banks may not have sufficient funds to offer CBDC on demand at all times.

Below, two scenarios are illustrated. First, under the "normal scenario", there is no systemic stress on the overall banking sector. Most depositors consider deposits to have very low default risks. Second, for the less likely "distressed scenario", there is a systemic stress on the banking sector. Runs into CBDC occur as deposits are judged to be significantly riskier.

Normal scenario

Just as banks hold cash to serve deposit withdrawals, they will also need to hold bank reserves to serve the conversion of deposits into retail CBDC. Current bank reserve levels at the BOT may not be adequate for this purpose since most existing reserves are held near the regulatory minimum of 1% of banks' deposits and borrowing. To ensure adequacy, banks would need to increase reserves significantly, and as noted in Part 2, retail CBDC adoption may substitute most cash usage. Therefore, we assume that the level of additional bank reserves required for CBDC would not exceed the present amount of cash that banks hold for withdrawals, or THB 260 billion[17]. Under this assumption, bank reserves may need to rise by at most 210% from the current level of THB 123 million, representing just over 5% of banks' high-quality liquid assets (HQLA) or 1% of total assets in December 2020.

Banks could wholly obtain these additional reserves since there are ample liquid assets within the banking system, reflected by the liquidity coverage ratio (LCR)[18] of 180% in December 2020. Banks could reduce parts of their HQLA that are not part of existing bank reserves or cash to fund the additional reserves required. With HQLA declining by 5% over many years, the LCR would decrease to 175%, all else equal. That will still be a very robust liquidity level compared with the minimum regulatory requirement of 100%. In practice, the actual amount of HQLA that needs to be liquidated could be yet lower than this. As CBDC increasingly displaces cash use, banks can substitute some of their cash holdings with bank reserves directly without sourcing additional funds.

With forward-looking preparation and asset management, risks to bank liquidity can be brought to very low levels. Nonetheless, this does suggest that the BOT supervision system should have a role in ensuring that banks have sufficient bank reserves according to each institution' projected deposit outflows.

[17] Average level of baht cash holdings by all commercial banks (2015-2020)

[18] LCR is the stock of HQLA divided by total net expected cash outflows over the next 30 days. For simplicity, the divisor of the LCR is here assumed to be constant.

Distressed scenario

The distressed scenario happens when depositors run from the overall banking sector into CBDC. For example, there could be a crisis of depositors' confidence after a nationwide shock increases the vulnerabilities of most borrower groups across different banks. Unlike the normal scenario, the banking sector did not internalize runs in their projection and did not prepare sufficient liquidity. If this occurs, there could be significant effects on monetary policy and financial stability. Banks may quickly deplete their stock of electronic reserves to serve withdrawals. If these reserves are not enough, this could prompt the use of BOT's standing lending facility, or could cause liquidity squeeze in the overnight money markets. If deposit redemption were still not stemmed, the large banks that are primary dealers (PDs) may reduce short-term collateralized lending (reverse repo) activities with the central bank, while other banks could sell off liquid assets to replenish their bank reserves. These activities may heighten financial market volatilities, leading short-term rates to diverge from the policy interest rate. The usual channels of open market operations may be disrupted.

It should be noted that the scenario described above has a very low likelihood. Historically, shocks to financial institutions have been heterogeneous in line with different loan exposures, and depositors switched from troubled financial institutions to those with lower perceived default risks. For example, during the 1997 Asian Financial Crisis, seven troubled Thai banks experienced 20 percent year-on-year deposit contraction, totaling THB150 billion, while eight other banks saw deposits rose by 12 percent[19]. For future crises that are marked by interbank funds re-allocation, retail CBDC would have a small impact. Moreover, it should not be forgotten that CBDC holders could deposit their money back fast, too, given the new technology. A quick restoration in confidence could thus prompt deposit flows back to banks.

Nevertheless, it is vital that the BOT minimizes the likelihood of the distressed scenario from the beginning. Different design options are possible:

• Conversion limits on how much deposits can be exchanged into CBDC within a given period of time, or limits on the end-of-period outstanding amount per retail CBDC account (Gurtler, et al., 2017; Meaning, et al., 2018; Bank of England, 2020): this also implies that one person or one legal entity can only hold one retail CBDC account.

• Multiple-tiered remuneration for retail users of CBDC (Meaning, et al., 2018; Bindseil, 2020; Wierts & Boven, 2020): should CBDC holders keep CBDC in their wallets beyond a certain level, they could face a punitive interest rate relative to other returns in the market; the rates could even be negative.

These design options could prioritize the access for those that use retail CBDC mainly for day-to-day transactions and have low end-of-period outstanding amounts, particularly small businesses, individuals, and non-profit organizations. One possible design for Thailand is the limit of THB 1 million outstanding amount per retail CBDC account. First, there is no arbitrage with the banking deposit insurance of THB 1 million offered by the

[19] คณะกรรมการศึกษาและเสนอแนะมาตรการเพิ่มประสิทธิภาพการบริหารจัดการระบบการเงินของประเทศเพื่อเป็นการป้องกันการเกิดวิกฤติการณ์ทางเศรษฐกิจ. (2547). รายงานผลการศึกษาโครงการแทรกแซงกิจการธนาคารพาณิชย์ในช่วงวิกฤตการณ์และนโยบายหาผู้ลงทุนใหม่. กรุงเทพฯ: ศสปป. หน้า 26.

Deposit Protection Agency (DPA) from 2021. Second, 98% of all deposit accounts of the private non-financial sector had outstanding amounts not exceeding THB 1 million as of June 2020, but made up only 24% of the total deposit value. Designs like this would mitigate the impact of potential deposit runs from the beginning.

In the extreme situation that the distressed scenario arises despite careful design, it is still possible for the central bank to step in and re-allocate back the liquidity that had been drawn away from the commercial banks (Brunnermeier & Niepelt, 2019). Parts of bank funding will thus switch from retail deposits to central bank funding, and liquidity risks would be resolved.

In sum, bank runs under adverse situations could pose high impact. However, given appropriate and forward-looking counter-measures, it is possible for all relevant sectors to reduce risks from the beginning, although that will always have to be weighed against reducing the user-friendliness of CBDC.

5. Conclusion

In the digital age, the fintech revolution has changed the nature of money into a digital form, with private currency issuers already adopting the new technology. This leads to the question of the public role in providing a more innovative, convenient, and user-friendly money to serve rapidly evolving user needs. The central bank may be required to provide a safe, accessible, reliable, and interoperable digital payment infrastructure on which different private sectors build financial innovation (Bank of Thailand, 2021). Additionally, although monetary policy remains firmly under the national jurisdiction, the BOT may need to cushion against uncertainties, especially the non-linear adoption of alternative currencies arising from network externalities which could weaken the sovereign currency.

The BOT should therefore stand ready to issue retail CBDC if and when the need arises. Potential developments that warrant close monitoring include global stablecoins of large private networks and foreign CBDCs. For instance, the Central Bank of the Bahamas became the first central bank to issue retail CBDC for public use in September 2020. The first Thai baht stablecoin was issued on the Terra platform in March 2021. Meanwhile, the Eurosystem would decide within 2021 whether to issue the digital euro. The DCEP pilot continues to expand in China before official launch in 2022, and Diem is currently waiting for the Swiss Financial Market Supervisory Authority's approval.

The decision about retail CBDC issuance would have to be weighed carefully. On the one hand, benefits would include an upgraded public money infrastructure for the digital age, reduced reliance on large payment platforms, reduced gray and black market activities, improved effectiveness of government transfers, and higher policy interest rate pass-through. However, there may also be potential risks, including balance sheet impacts on the central bank, as well as risks to commercial banks, such as disintermediation and liquidity risks.

Further study on retail CBDC that covers more aspects is needed for informed policy decisions. Areas to consider include, for instance, CBDC impacts on future central bank balance sheet and monetary operations, impacts on monetary aggregate and velocity affecting real economy and inflation, impacts on the exchange rate and capital flows of small open economies, linkages with new global currencies and future digital financial landscape, as well as the optimal spread between CBDC and central bank's policy rate should CBDC be interest-bearing. These should be underpinned by robust further research, and, where relevant, by empirical evidence such as pilot projects.

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Appendix

Appendix I. – Scoring system from the money user's perspective

Criteria	Internet and mobile banking (used with deposits)	Remunerated retail CBDC	Unremunerated retail CBDC	Cash	Checks (used with demand deposits)	E-money	Baht-backed stablecoins	Other stablecoins
Speed	3 Fast fund transfer	3 Fast fund transfer	3 Fast fund transfer	1.5 Withdraw by going to bank branches or ATM	1 Need to wait for the check to clear	3 Fast fund transfer	3 Fast fund transfer	3 Fast fund transfer
Scalability	3 No limitation on value per transaction	3 No limitation on value per transaction	3 No limitation on value per transaction	2.5 No limitation on value per transaction but not portable	3 No limitation on value per transaction	1.5 Limitation on value per transaction depending on the service provider	2 Limitation on value per transaction depending on the service provider and regulation	3 No limitation on value per transaction
Domestic Acceptance	3 Acceptance from both payer and payee	3 Acceptance from both payer and payee	3 Acceptance from both payer and payee	3 Acceptance from both payer and payee	2.5 Maybe rejected by some payee	2 Network limitations	1.5 Limited	0.5 Limited
Extra domestic services	3 Access to other bank services	3 Access to other financial services	3 Access to other financial services	0.5 Limited	3 Access to other bank services	2 Depends on the service provider	2 Depends on the service provider	1.5 Limited by regulation
Interest returns	2 Deposit rates	1 Low rates due to cash-like nature	0 No return	0 No return	0 No return	0 No return	0 No return	0 No return
Anonymity	0 Verification required and payments can be tracked	0 Verification required and payments can be tracked	0 Verification required and payments can be tracked	3 No verification required and payments cannot be tracked	0 Verification required and payments can be tracked	0 Verification required and payments can be tracked	0 Verification required and payments can be tracked	2 Verification required in some cases, but payments cannot be tracked

Criteria	Internet and mobile banking (used with deposits)	Remunerated retail CBDC	Unremunerated retail CBDC	Cash	Checks (used with demand deposits)	E-money	Baht-backed stablecoins	Other stablecoins
Transaction costs	3 No transaction fees	3 No transaction fees	3 No transaction fees	1.5 Shoe leather cost and storage costs for high amounts	1 Transaction fees levied	2 Transaction fees levied in some cases	1 Transaction fees levied	1 Transaction fees levied
Default risks	2.5 Low risks in line with the risk of the financial institution	3 Risk-free (issued by central bank)	3 Risk-free (issued by central bank)	3 Risk-free (issued by central bank)	2.5 Low risks in line with the risk of the financial institution	3 Risk-free (service provider needs to deposit all the pre-paid money at financial institutions)	3 Risk-free (fully backed by deposits)	1 Technological risks of each platform, or operational risks
Settlement risks	3 None	3 None	3 None	3 None	1.5 Some risks from double payments	3 None	3 None	3 None
Criminal law protection	0 None	0 None	0 None	0 None	3 Check bouncing is a criminal offense	0 None	0 None	0 None
Total	**22.5**	**22**	**21**	**18**	**17.5**	**16.5**	**15.5**	**15**

Source: Authors' assessment for Thai case; scoring criteria adapted from Mancini-Griffoli et al., 2018 (highest score = 3, lowest score = 0)

Appendix II. – Bass model for technology diffusion

The Bass model (1969) is still widely used to analyze technology diffusion and predicting the pattern and speed of technology adoption. The model assumes that potential adopter of retail CBDC can be divided into two groups: (1) innovator - the first group of people who adopt retail CBDC are influenced solely by advertisement, and (2) imitator – the second group who are influenced by information received from the innovators.

In applying the Bass model, we derive retail CBDC adoption at time t from the following formula:

$$n_t = p(m - N_{t-1}) + \frac{q}{m}(N_{t-1} * [m - N_{t-1}])$$

where

$n_t =$ additional CBDC adopted in period t

$m =$ the market potential of CBDC

$N_t =$ cumulative CBDC adoption at the beginning of period t

$p =$ coefficient of innovation

$q =$ coefficient of imitation

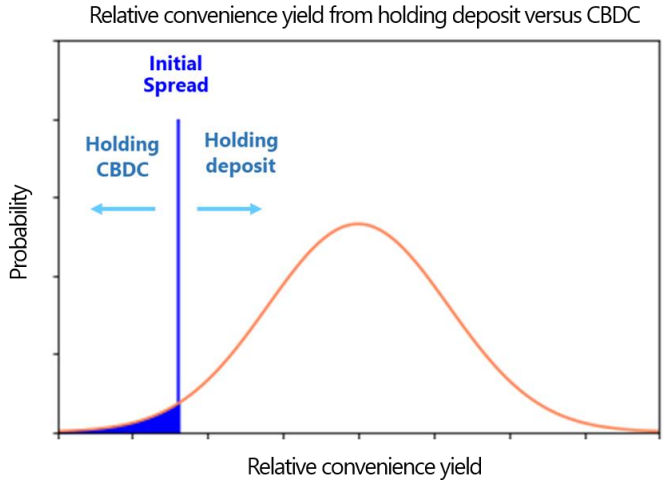
Appendix III. – Relative convenience yield from holding deposits over CBDC

People are expected to weigh costs and benefits of deposit and retail CBDC differently, their relative convenience yield from holding deposit versus CBDC ($\phi_{i,t}^{d}$) is therefore heterogeneous. For example, people that deposit very small amount of money in their accounts with few transactions via these accounts may experience high cost of holding deposits, their relative convenience yield will be low. On the contrary, corporates would prefer to hold large amount of money in their deposit accounts for extra financial services from banks including lending, their relative convenience yield will be higher.

That is, for an individual i, relative convenience yield from holding deposits versus CBDC's ($\phi_{i,t}^{d}$) depends on the individual's utility function

$$\phi_{i,t}^{d} = u_{i,t}(r_{1,t}, \dots, r_{p,t}, b_{1,t}, \dots, b_{q,t}).$$

Assuming that $f(\phi_{i,t}^{d})$ is a probability density function of $\phi_{i,t}^{d}$ with the following shape



After introducing CBDC, banks will set the spread between CBDC rate and deposit rate ($i_t^{CBDC} - i_t^{d}$) at χ_t^{d}. For an individual i,

If$\chi_t^{d} = \emptyset_{i,t}^{d}$, an individual is indifferent between holding deposits and CBDCs

If $\chi_t^{d} > \emptyset_{i,t}^{d}$, an individual prefer holding CBDC to deposit

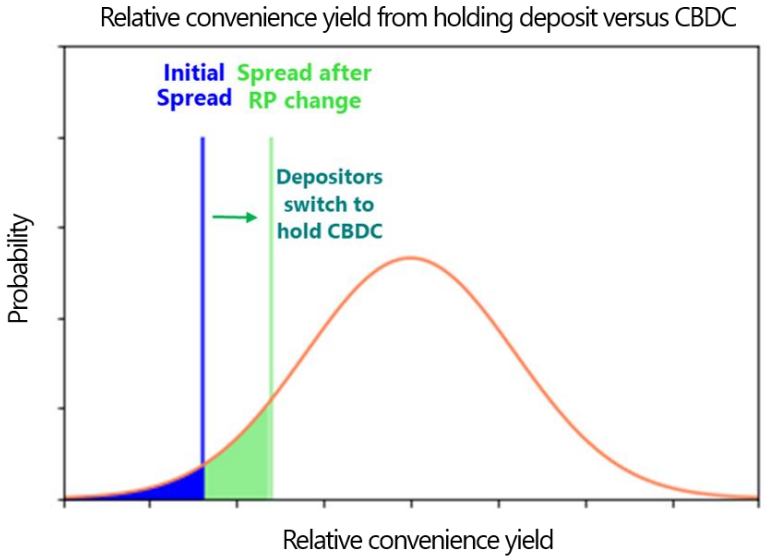
If $\chi_t^{d} < \emptyset_t^{d}$, an individual prefer holding deposit to CBDC

The higher the spread χ_t^{d}, the more deposit banks will lose. As a result, χ_t^{d} is determined by how much deposit banks want to keep after the introduction of CBDC. This interaction between deposit movement and spread adjustment can help improve monetary policy transmission through deposit rate pass-through as described in appendix IV.

Appendix IV. – Retail CBDC and bank rate pass-through

With the initial setting introduced in Appendix III, an increase in the policy rate will automatically increase the spread χ_t^d as the spread between policy rate and CBDC is always fixed while pass-through to deposit rate is less than one-to-one.

That is, $i_{t+1}^{CBDC} = i_t^{CBDC} + \Delta RP$ while $i_{t+1}^d = i_t^d + \beta\Delta RP$, $(\beta < 1)$, so the spread increases to $i_{t+1}^{CBDC} - i_{t+1}^d = \chi_{t+1}^d{}' = \chi_t^d + (1-\beta)\Delta RP$. This increase in the spread will cause banks to lose deposits since depositors with $\chi_t^d < \phi_{i,t+1}^d < \chi_{t+1}^d{}''$ will switch to CBDC. Hence, banks may choose to decrease the spread $\chi_{t+1}^d{}''$ by increasing deposit rate further $\Delta\chi = \gamma\Delta RP$, potentially improving deposit pass-through.



To what extent the pass-through could be improved (γ) will depend on potential deposit outflows $\int_{\chi_t^d}^{\chi_{t+1}^d{}'} f(\phi_{i,t})\, d\phi_{i,t}$ (shaded area) and how much deposit banks want to maintain. If potential outflows are large, banks are likely to raise deposit rate by large amount ($\Delta\chi$ is large). This implies that large potential outflows could result in better transmission. Likewise, if target level of deposit is high, banks are likely to raise deposit rate by a large amount to remain attractive, thereby improving the pass-through. If banks raise deposit rate by $\Delta\chi = \gamma\Delta RP = (1-\beta)\Delta RP$, the spread will remain unchanged ($\chi_{t+1}^d = \chi_t^d$). In this extreme case, the change in the policy rate can be fully transmitted. However, if potential deposit outflows are small while banks do not set high level of target deposit, banks are unlikely to adjust deposit rate and transmission remains the same.