New payment portfolio model and policy impact

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Abstract

Our study presents a new portfolio theory for various newly emerging payment methods as the development of the cryptocurrency market and the development of digital currency by the central bank (CBDC) accelerates. This study deals with what payment method an individual chooses under given conditions by adding interest rates that may be imposed on CBDC and stablecoins used on cryptocurrency exchanges. In addition, this study deals with the impact of these CBDC and stablecoins on the choice of existing cash and deposit and what additional changes are made according to the government's exogenous macro-economic policy.

Keywords: Central Bank Digital Currency, Cryptocurrency, Payment portfolio model, Stablecoin

JEL classification code: E41, E58

1. Introduction

Distributed ledger and blockchain technology, which emerged with the development of information technology, led to the emergence of cryptocurrency. With the emergence of cryptocurrencies represented by Bitcoin, discussions arose over whether a new currency would replace existing currencies. In this situation, discussions on the digitalization of money began in earnest as several central banks around the world considered introducing a new digital currency called Central Bank Digital Currencies (CBDC). CBDC is a currency issued by a central bank in the form of nominal replacement of existing legal currencies, but it has several properties arising from digitalization.

The nature of CBDC, which is distinct from cash, is used to evaluate the effectiveness of new monetary policies among several policy researchers. This is because CBDC not only replaces physical currency but can also affect deposits due to its special nature. However, existing literature analyzing the impact of CBDC oversimplifies individual portfolio changes considering CBDC, because there is a lack of research on the existing payment portfolio model. Studies that analyze the impact of CBDC on the macroeconomy show changes in individual agents' choices, mainly limited to the specific nature of CBDC. In other words, only fragmentary properties such as interest rate and anonymity are considered in current studies. In addition, since the existing portfolio theory has mainly dealt with asset selection, only a few studies analyze the payment portfolio model. Unlike assets such as equities or bonds, money's characteristic as a general payment method is that it preserves value and is used as a medium of exchange. In recent years, with the development of information technology, the types of

payment methods have extended not only to cash but also to deposit, credit cards, and debit cards, raising the need to consider the portfolio of payment (Schuh and Stavins, 2013; Schuh and Stavins, 2014; Bian, Ji, and Wang, 2021). Moreover, as payment assets such as CBDC and cryptocurrencies are expected to be newly added, the number of assets to be included in the future payment asset portfolio is also increasing.

Especially, it is necessary to pay attention to the introduction of cryptocurrency and its use as a payment asset. Nowadays, as interests in cryptocurrency increase, people's interests and demands for cryptocurrency continue to rise, shown by listing on the NASDAQ of Coinbase, a global cryptocurrency exchange, and listing on the New York Stock Exchange of a Bitcoin Futures Exchange. Now, it is common to see cryptocurrency such as Bitcoin being effectively incorporated into the financial system. Similar to existing payment assets such as cash, CBDC, and deposit, cryptocurrency has its own unique properties. By adding cryptocurrency to the payment asset portfolio model, a more sophisticated analysis can be done by comparing it with existing payment assets.

However, in the case of cryptocurrency, it is often recognized as an asset rather than money (Baur, Hong, and Lee, 2018). Because it does not satisfy the function of a store of value due to its price volatility, its use as a widely accepted currency has a dark future. Therefore, even if cryptocurrencies are incorporated into the payment portfolio model, it will be clear to analyze some cryptocurrencies that have actual uses as money.

Generally, the types of cryptocurrency can be classified according to the form of compensation from mining or according to the purpose of use. In the case of general cryptocurrency, the volatility of its value is high, so for the analysis in the payment asset model, analyzing a cryptocurrency with low price volatility and a constant value is necessary. An example of this is stablecoin, to which cash assets such as dollars and their values are constantly linked, such as the Libra project promoted by Meta in the past (now Diem). Currently, the most used stablecoin in terms of liquidity is Tether, which is an asset that is mainly used for money transactions between cryptocurrency market exchanges (Kristoufek, 2021). Tether is designed so that one tether unit has the same value as a US dollar, so it is reasonable to classify it as a payment asset in terms of volatility. Therefore, in our study, stablecoins focused on Tether coins are considered in the portfolio model.

In addition to considering the new payment assets, we also present a discussion of interest rates that have not been addressed in existing payment portfolio studies. In the above paragraph, we already have presented that CBDC can be charged interest rates. This property is important in that an agent considers a payment asset. Reflecting the interest rate of CBDC suggests implications for analyzing the impact of the central bank's monetary policy on individual portfolio changes.

Discussing the problem of agents' optimal portfolio choice with the emergence of new payment assets, our study has the following contributions. First, we classify and present the types and properties of payment assets including new currencies that will appear as technology advances. There are several empirical studies about agents' payment asset choice, but theoretical studies explaining the properties of each payment asset are scarce (Qu, Wei, and Zhang, 2022; Schuh and Stavins, 2013; Schuh and Stavins, 2014). Therefore, our analysis can contribute to classifying and analyzing the characteristics of payment assets that will appear in

the future. Second, we explain the substitution between payment assets according to changes in exogenous conditions focusing on the features of payment assets. Analyzing the relationship between payment asset properties and an agent's portfolio can be helpful in future policy studies dealing with the process of agent's choice change according to the change in the feature of the payment asset or agent's preference. Third, analyzing the impact of payment asset properties, we discuss not only the subjective utility factors that agents face, but also the policy variables which can impact agents' utility such as interest rate. Also, presenting the impact of interest rate gap changes between CBDC and deposit, we can also provide implications for macroeconomic studies such as banking crisis and financial stability by dealing with the impact of CBDC issuance on agents' payment asset choice problem.

The paper is organized as follows. In Section 2, we suggest relevant research, payment assets, and their properties. We introduce a concrete model and address the problem of consumer portfolio selection in Section 3. Section 4 summarizes the discussion and concludes.

2. Payment assets and their properties

In this section, we present the principle of the payment portfolio model by classifying the types and properties of payment assets. Bian, Ji, and Wang (2021) propose a simple payment portfolio model and present a portfolio that an agent selects when three payment assets (Cash, Deposit, and CBDC) exist. In our study, we modify his framework and extend the analysis by adding a stablecoin as a payment asset and subdividing the existing properties. In their study, for simplicity, the interest rate on CBDC is not considered. They also note that the issuance of CBDC may affect the demand for deposits due to its properties such as legal tender and digital currency. However, in many macroeconomic studies, the imposition of interest on money is one of the most important features of CBDC mentioned as an alternative to Friedman's rule. Moreover, because the imposition of an interest rate on money is a key feature that can affect deposit demand (Andolfatto, 2021; Jia, 2020; Williamson, 2021), it is essential to further consider interest rates when analyzing the crowding-out effect. In our study, payment assets refer to assets with sufficient liquidity to be used in daily transactions. There are four types of payment assets: cash, deposit, CBDC, and stablecoin. Among the payment assets we consider, CBDC and stablecoin are not widely used in daily transactions, but are considered to be used in the future, so they are reflected in our model. The description of each is as follows.

2.1 Cash

Cash is a basic payment asset issued by the central bank. As a physical currency, payment using cash is still used worldwide as a means of value exchange for physical transactions, such as buying and selling goods in the market. Moreover, classical macroeconomic models such as Cash in Advance and Money in Utility generally use cash as a basic form of money. Because cash is issued by the central bank generally, it has a property of legal tender, whose value is guaranteed legally. Another property of cash is anonymity. A daily transaction with cash does not leave any transaction traces generally. Therefore, it can also be used as an asset for illegal

transactions such as money laundering (Kim, Bilgin, and Ryu, 2021; Kahn, 2018). In addition, as Borgonovo et al. (2021) mentioned, transactions that guarantee anonymity are also important in terms of privacy protection. In particular, privacy has become more important information in the information age (Acquisti, Alessandro, and Brandimarte, 2015). In short, discussing cash as a payment asset, we suggest that cash has two utility-contributing properties: legal tender and anonymity.

2.2 Deposit

A deposit is a representative interest-bearing payment asset. In addition, being linked with a debit card, it is often used for simple payments (Kim, Mirusmonov, and Lee, 2010). Generally, its simple payment function is indicated by the electronic characteristics, and we consider this property as a utility-contributing feature as it gives the convenience of transaction. In other words, payment assets issued in electronic form like deposits can improve the physical inconvenience of transactions using cash currency. Digital currencies' utility-contributing features can also be found in the study of Ching and Hayashi (2010). They conduct a hypothetical experiment to abolish loyalty rewards using credit cards, and conclude that only the substitution between the debit card and the credit card mostly occur but the demand for cash hardly increases. This shows that a consumer's convenience in using digital currency is an important characteristic when selecting a payment asset. Another study about payment asset substitution by Humphrey, Kim, and Vale (2001) investigates substitution elasticities between cash, debit cards, and cheques to analyze the relationship between payment systems and social costs following the advent of electronic payments. By revealing that a debit card is a strong substitute for a cheque, they argue that the electronic payment characteristic of money have a strong influence on consumer choices. By the way, a credit card is also linked to a bank account and can be used by the consumer who pays monthly interest. At this time, interest is the user fee that the consumer pays to use the credit card. Because debit cards and credit cards have different characteristics, different effects appear even if both are linked to a bank account. Use of a credit card has utility-contributing properties that enable consumption in excess of the consumer's current cash holdings, but may reduce the consumer's utility in that interest may be charged. In addition, since consumer utility can vary depending on the credit card's interest charging method, it is difficult to analyze a portfolio considering a credit card (Shy, and Wang, 2011). Therefore, for simplicity, products linked to deposits are limited to debit cards. According to these discussions, we consider digital currency as a utility-contributing property of payment asset and assume that deposit is a digital currency and has interest-bearing property.

2.3 CBDC

CBDC is a virtual currency issued by the central bank, so it can be classified as legal tender like cash. In addition, as it is issued in electronic form like a deposit, it has the property of digital currency and is convenient when used as a payment asset. Furthermore, interest can be charged like deposit. Although few countries are using CBDCs directly as fiat currencies, research on this is actively taking place at each central bank. CBDC can be divided into several

types depending on its use, and we focus on retail CBDC in that it is expected to be used by general consumers. The wholesale CBDC that can be used for interbank transactions is not very different from the existing financial system (Bindseil, 2020), so it appears that there is little need for analysis in this paper. Bian, Ji, and Wang (2021) do not consider the interest rate of CBDC because it is always smaller than deposit. However, lots of economic studies on CBDC have treated the interest rate of CBDC as an important characteristic. Andolfatto (2021) and Davoodalhosseini (2021) claim that monetary policy using CBDC is one of the general policies that central banks can consider when issuing CBDC. Jia (2020) also mentions that it is possible to realize the imposition of interest rates on reserves as an alternative means to achieve the optimal quantity of money as suggested by Friedman (1969). Commonly, they explain the monetary policies that central banks can use when issuing CBDC and their effects, focusing on interest rates. In other words, since the interest rate on CBDC is a property widely considered by central banks and academia in each country, it is essential to develop a model that reflects it. On the other hand, as Bian, Ji, and Wang (2021) mention, because CBDC is expected to have higher safety than deposit since it is legal tender, the interest rate levied on it is expected to be lower than deposit. Therefore, we intend to provide an extended discussion focusing on interest rates, in consideration of these contents. Although not covered in detail in our study, another thing to consider is the government's compulsory retention policy and negative interest rate policy (NIRP). These policies are factors that can change a consumer's portfolio exogenously. In conclusion, we consider three important properties of CBDC in this model: digital currency, legal tender, and interest-bearing.

2.4 Stablecoin

Cryptocurrencies such as bitcoin and Ethereum are perceived to have a low possibility of replacing existing currencies due to price volatilities. Unlike the risky existing cryptocurrency, stablecoin is a cryptocurrency created to function as a currency by maintaining the same value as real money while providing convenience using blockchain technology. Stablecoin can be divided into fiat-money-based, cryptocurrency-based, and commodity-based depending on which product the value is matched with. In our study, as we want to consider stablecoin as a payment asset, we will focus on fiat-money-based stablecoin, which has the same fixed value as money. There are various types of fiat-money-based stablecoins, and in our study, stablecoins are described focusing on Tether which is the most widely traded in the global cryptocurrency market. Since stablecoin is not issued by a government, we do not regard it as legal tender, but using decentralized ledgers, stablecoin has the property of anonymity in that it is generally impossible to trace transactions. Moreover, as transaction participants even may not know each other's information, stablecoin can be regarded as an asset with stronger anonymity than cash. However, since the difference in cash and stablecoin regarding privacy is not seen to be as large as the differences between the two payment asset and other payment assets, we assume that the utility from the anonymity of the two assets is identical.

3. Payment portfolio model

In this section, we analyze the choice process of agent's payment assets. As we have explained above, the agent faces the utility maximization problem of constructing a portfolio with four types of payment methods classified as cash, deposit, CBDC, and stablecoin. In this case, the agent's problem can be expressed as the following equation (1).

$$\max U = U(Cash, Deposits, CBDC, Stablecoin)$$
$$s.t. M = Cash + CBDC + Deposits + Stablecoin \quad (1)$$

For simplicity, we assume that the consumer's utility function is quasi-linear. By using the quasi-linear utility function, it may not be possible to accurately study consumer preferences regarding interest rate preferences. However, in that the CBDC interest rate determined by the central bank is considered in the model as an additional policy variable and changes in consumer portfolio composition are analyzed accordingly, the function can have the advantage of analyzing asset substitutions. Under these discussions, we assume that the properties such as legal tender, anonymity, and digital currency all use a natural logarithmic function that stands for diminishing marginal utility, while it is assumed that the utility-contributing interest rate is linear. In addition, in our study, we used only the variables that directly affect an agent's portfolio choice. In an actual transaction, there may be a payment asset that the counterparty wants to use as a payment method (Faccio, and Masulis, 2005). In order to close the transaction for the agent, this phenomenon may affect the portfolio selection. However, for simplicity, we do not reflect this argument in our portfolio choice model. According to these conditions, the agent's utility function is specified as follows.

$$U(Q_L, Q_A, Q_D, Q_I) = \log(Q_L^l Q_A^a Q_D^d) + \beta\{R_{CBDC}\varphi + R_{Deposit}(1-\varphi)\}Q_I \quad (2)$$

Q_i denotes the total holding amount of a payment method having the property of i, and i satisfies $i \in \{L, A, D, I\}$. Each of l, a, and d means the exponent of Q_i except Q_I and satisfies $0<\min(l, a, d) < 1$ and $l + a + d = 1$. For example, since cash and CBDC have the properties of legal tender in common, Q_L is equal to 6 when the agent holds 3 units each. $R_{Deposits}$ and R_{CBDC} denote the interest rates imposed to the deposit and CBDC, respectively, and β is a discount factor and satisfies $\beta > 0$. In this case, the meaning of the discount factor is as follows. l, a, and d are an agent's subjective variables, whereas $R_{Deposits}$ and R_{CBDC} related to the interest rates are exogenous variables. Therefore, the discount factor adjusts the numerical gap between them. φ denotes the holding ratio of CBDC among the assets that give the interest, $\varphi = \frac{CBDC}{Deposit+CBDC}$. The following **Table1** summarizing Q_i for each payment asset is as follows.

Table 1
The utility contributing properties of payment assets

	Legal tender	Digital currency	Anonymity	Interest
Cash	1	0	1	0

Deposit	0	1	0	$R_{Deposit}$
CBDC	1	1	0	R_{CBDC}
Stable coin	0	1	1	0

Table 1 shows the relationship between the properties that influence an agent's portfolio choice and the payment assets. While the payment asset has a property corresponding to each column, that it has the property is indicated as '1' in the table. On the contrary, it is indicated as '0' if the payment asset does not have the corresponding property. Unlike other characteristics, in the case of interest rate, since it is a variable that reflects actual monetary policy, it does not appear binary. Since the interest rate on CBDC is generally lower than the deposit, we assume $R_{CBDC} \leq R_{Deposit}$. On the other hand, when NIRP is charged on CBDC, there may be a case where $R_{CBDC} < 0$. Now, based on the table above, the constraint condition of the agent is as follows.

$$Q_L = Cash + CBDC \tag{3}$$
$$Q_I = CBDC + Deposit \tag{4}$$
$$Q_A = Cash + Stablecoin \tag{5}$$
$$Q_D = CBDC + Deposit + Stablecoin \tag{6}$$
$$M = Cash + CBDC + Deposit + Stablecoin \tag{7}$$

Equations (3)-(7) are the most basic and general forms that reflect the properties of each currency discussed in Section 2. Note that these equations are also variables, as the properties of payment assets may vary depending on the monetary policy or law of each country. In our study, we take these equations as the basis model, and explain how the basis model changes according to exogenous changes such as law or monetary policy, and how the optimal payment portfolio of the agent can change accordingly.

3.1 A basis model

In the basis model, we present a solution that maximizes the objective Equation (2) under the constraint, Equations (3)-(7). Equations (8)-(11) summarize the optimal payment portfolio of the basis model. For the convenience of description, let $R_{Deposit} = R$.

$$Cash^* = M - \frac{D}{(R - R_{CBDC})\beta} \tag{8}$$
$$Deposit^* = 2M - \frac{A}{R\beta} - \frac{D+L}{(R - R_{CBDC})\beta} \tag{9}$$
$$CBDC^* = -M + \frac{D+L}{(R - R_{CBDC})\beta} \tag{10}$$
$$Stablecoin^* = -M + \frac{A}{R\beta} + \frac{D}{(R - R_{CBDC})\beta} \tag{11}$$

In Equations (8)-(11), the case of holding certain amounts of all four types of payment assets satisfies $\min(Cash^*, Deposit^*, CBDC^*, Stablecoin^*) > 0$. So, the necessary and sufficient

condition for holding all payment assets is $\frac{A}{R} < \frac{D+L}{R-R_{CBDC}}$. If this condition is not satisfied, some assets may not be contained in the portfolio. The above portfolio equations suggest how the optimal choice appears according to the size of the preference of the agent. For example, the demand for cash is affected by convenience due to digital currency and the interest rate gap between deposit and CBDC, and the demand for deposit is affected by anonymity, the interest rate of deposit, digital currency, and legal tender. This shows that the composition of preferred payment assets can vary depending on the heterogeneity of preference placed on the agent. According to this principle, the change in the composition of the payment portfolio according to the change in the properties of the payment assets is analyzed as follows.

First, when the demand for legal tender increases, since $Deposit_L < Cash_L, Stablecoin_L = 0 < CBDC_L$ holds, the demand for deposit decreases, and the demand for CBDC increases. In other words, an increase in preference for legal tender will result in substitution between deposit and CBDC. Second, when the demand for digital currency increases, since $Cash_D = Deposit_D < 0 < CBDC_D, Stablecoin_D$ holds, the demand for cash and deposit decreases, and the demand for CBDC and stablecoin increases. The interpretation of the decrease in the demand for deposits despite the fact that deposit, CBDC, and stablecoins all have the features of digital currency can be explained as follows. Since the utility function is assumed to be linear with respect to the interest rate, the properties of anonymity and legal tender are the main considerations in the optimal choice. Since a deposit is a payment asset that is inferior in terms of anonymity and legal tender to CBDC and stablecoin among assets that share digital properties, it appears that the demand for deposit decreases as the demand for CBDC and stablecoin increases relatively. Next, when the demand for anonymity increases, since $Deposit_A < Cash_A, CBDC_A = 0 < Stablecoin_A$ holds, a substitution between deposit and stablecoin occurs. Finally, the portfolio when there is a change in the interest rates levied on deposit and CBDC is as follows. First, if the interest rate charged to the deposit increases, since $CBDC_R, Stablecoin_R < 0 < Cash_R < Deposit_R$ holds, the demand for deposit and cash increases, and the demand for CBDC and stablecoin decreases. In addition, when the interest rate imposed on CBDC increases, since $Deposit_{R_{CBDC}} < Cash_{R_{CBDC}} < 0 < Stablecoin_{R_{CBDC}} < CBDC_{R_{CBDC}}$ holds, the demand for CBDC increases the most. In this process, a change in preference for a specific feature of a payment asset does not necessarily cause a change in every single asset in the portfolio.

3.2 A model without CBDC

Although many central banks around the world are promoting the issuance of CBDC, the need for it is still being discussed academically. In other words, there are countries that do not issue CBDC, and the situation in countries where CBDC are not issued can be seen as such. In this case, the analysis of the agent's payment asset portfolio is as follows.

$$Cash^* = M\left(\frac{L}{D+L}\right) \tag{12}$$

$$Deposit^* = M - \frac{A}{R\beta} \tag{13}$$

$$Stablecoin^* = -M\left(\frac{L}{D+L}\right) + \frac{A}{R\beta} \tag{14}$$

In this case, the necessary and sufficient condition for holding all payment assets is $M\left(\frac{L}{D+L}\right) < \frac{A}{R\beta} < M$. In the above equations, the demand for cash is affected by digital currency and legal tender, and deposits are affected by anonymity and interest rate, and stablecoin is affected by legal tender, digital currency, anonymity, and interest rate. In this case, CBDC is not issued by the central bank and it is similar to a situation where people can trade coins due to the promotion of stablecoin transactions by the government. Now, the portfolio change according to the preference change of payment asset features is analyzed as follows.

First, when the preference for legal tender increases, since $Stablecoin_L < Deposit_L = 0 < Cash_L$ holds, a substitution between cash and stablecoin occurs. Intuitively, since the cash is a legal tender unlike a stablecoin, the substitution between these assets can be easily confirmed. On the other hand, in the case of a deposit, substitution does not occur even if it is not a legal tender. This situation can be interpreted as that the utility obtained by the agent from the interest rate is linear, and since the properties held by the deposit are independent of cash, the substitution does not occur. Second, when preference for digital currency increases, since $Cash_D < Deposit_D = 0 < Stablecoin_D$ holds, substitution between cash and stablecoin can appear. Also, when the preference for anonymity increases, since $Deposit_A < Cash_A = 0 < Stablecoin_A$ holds, a transfer between deposit and stablecoin occurs. Finally, if the interest rate of deposit increases, since $Stablecoin_R < Cash_R = 0 < Deposit_R$ holds, the transfer between deposit and stablecoin occurs. It can be analyzed as a substitution effect resulting from a decrease in the demand for stablecoins in line with the increased demand for deposit, because deposit and stablecoin are both digital currencies.

3.3 A model without cash

The central bank may have a policy purpose of ultimately replacing cash with the form of CBDC for convenience and policy efficiency due to the use of digital money. In this case, we can discuss the case that the entire amount of cash is replaced with CBDC. That is, all payment assets have properties of digital currency in common, and the agent's optimal portfolio is as follows.

$$Deposit^* = M - \frac{L}{(R-R_{CBDC})\beta} - \frac{A}{R\beta} \tag{15}$$

$$Stablecoin^* = \frac{A}{R\beta} \tag{16}$$

$$CBDC^* = \frac{L}{(R-R_{CBDC})\beta} \tag{17}$$

In this case, the necessary and sufficient condition for holding all kinds of payment assets is $0 < \frac{L}{(R-R_{CBDC})\beta} + \frac{A}{R\beta} < M$. In the above equations, unlike the analysis in the previous section, demand for a digital currency does not affect any portfolio composition change. Because cash

currency disappears, all payment assets have a property of digital currency commonly and the increase in agent's demand for a digital currency does not affect the asset portfolio composition. That is, the marginal utility of each payment asset for digital currency property is zero ($CBDC_D = Deposit_D = Stablecoin_D = 0$). Now, the portfolio change according to the preference change of payment asset properties is as follows.

First, if the demand for legal tender increases, since $Deposit_L < Stablecoin_L = 0 < CBDC_L$ holds, a substitution between deposit and CBDC occurs. This is because all payment assets are digital currencies, and the interest-bearing property has a linear effect on utility. In other words, since deposit has unique features of bearing interest and stablecoin has the property of anonymity, substitution between deposit and CBDC can appear. Finally, the portfolio change when the interest rate increases is as follows. First, if the interest rate charged on deposit increases, since $CBDC_R, Stablecoin_R < 0 < Deposit_R$ holds, the demand for deposit increases and the demand for CBDC and stablecoin decreases. Intuitively, since the interest rate on deposit increases, a substitution between CBDC, stablecoins, and deposit can appear. However, if the interest rate imposed on the CBDC changes, since $Deposit_{R_{CBDC}} < Stablecoin_{R_{CBDC}} = 0 < CBDC_{R_{CBDC}}$ holds, only the replacement between the CBDC and the deposit occurs. The intuition for these results is as follows. In the former case, unlike the rest of the payment assets, the deposit does not have the properties of anonymity and legal tender, so the substitution effect according to the increases in the interest rate appears in all the remaining payment assets. On the other hand, in the latter case, since the demand for CBDC which is a legal tender increases, the demand for stablecoin with anonymity does not change and only the demand for deposit decreases.

3.4 A model without anonymity on stablecoins

Due to the anonymous property of money transactions using cryptocurrencies, money laundering is taking place on many cryptocurrency exchanges (Kim, Bilgin, and Ryu, 2021). Money laundering or tax evasion due to anonymity can cause lower social welfare compared to an economy where the central bank can control anonymity (Kwon, Lee, and Park, 2020). Therefore, there is an incentive for the central bank to provide a legal mechanism to request the transactional records of personal accounts from domestic cryptocurrency exchanges. In this case, the anonymous property of stablecoin may disappear. Since the utility-contributing features of stablecoin are limited to the property of digital currency, it becomes an inferior asset compared to other payment assets such as CBDC or deposit. In other words, since the marginal utility due to the use of stablecoin is always smaller than CBDC or deposit, the demand for coins becomes zero.

3.5 A model with the same deposit and CBDC interest

Now, we want to analyze the direct effect of the policy of charging interest rates on CBDC on the demand for deposits. As mentioned above, CBDC is generally expected to be charged a lower interest rate than deposit. When we suppose that charging the same interest rate on CBDC

as deposit, the impact of issuing CBDC on deposit can be easily understood. In this case, the theoretical result is that the agent does not hold any deposit. Since CBDC and deposit have the properties of digital currency in common, if the same interest rates are applied, a strong preference for CBDC which is a legal tender appears. The result is also related to the existing literature that when an interest rate above a certain level is levied on CBDC, a commercial bank's profitability can be affected negatively (Andolfatto, 2021; Jun, and Yeo, 2021).

4. Conclusion

We analyze an agent's optimal payment asset portfolio choice process, focusing on changes in exogenous conditions. We derive the agent's optimal portfolio choice from the properties of the four payment assets. Moreover, we show how the agent's choice changes when the properties of the payment asset change. In addition, we explain that with the diversification of payment methods, the unique features of each payment asset can be important factors in determining the demand for that asset. When all cash is replaced with CBDC, an agent's asset reallocation method can also be different as characteristics such as digital currency do not affect the change of portfolio choice. In addition, we show that the demand of cryptocurrency as a currency can sharply decrease when properties such as anonymity disappear. The issuance of CBDC and the possibility of replacing cash, the interest that can be charged on CBDC, and the regulation of anonymity to prevent money laundering by cryptocurrency exchanges are economic actions that central banks and governments can consider. Therefore, it is important for policymakers to understand how agents change the payment asset portfolio in each case. Finally, our study also suggests implications for the profitability of commercial banks, which can be said to be one of the important issues of CBDC. We analyze the substitution effect between the agent's CBDC and deposit from various perspectives by considering features such as legal tender as well as the interest rate.

Declaration of competing interest

Acknowledgements

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