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The trilateral game of privacy perception, financial regulation and central bank digital currency issuance

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Abstract

The goal of this study is to clarify how privacy protection affects the insurance of central bank digital currency (CBDC). By constructing a tripartite game model involving consumers, commercial banks, and regulators, this paper explores the impact of privacy protection on the issuance of CBDC. The findings show that privacy protection is critical to ensuring successful adoption of CBDCs. The central bank must strike a balance between protecting user privacy while also regulating usage and ensuring convenience for users. However, due to opportunistic behavior by both commercial banks and consumers during this process, negative reactions are possible. Based on the findings of this research, it is suggested that central banks should encourage commercial banks to participate in CBDC issuance by promoting appropriate data sharing and offering guidance. Additionally, they should focus on consumer education and expectation management to promote CBDC adoption. Commercial banks must also embrace digital transformation and adapt to the changing financial landscape to remain competitive while providing innovative financial services to customers.

Keywords:
CBDC
Financial regulation
Game theory
Privacy perception.

JEL Classification:
D18; E59; G18; G2.

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1. Introduction

With the ongoing advancements in technology and the emergence of new innovations, such as mobile payments and trusted cloud computing, traditional paper currencies issued by central banks are facing a multitude of challenges. In contrast, digital currencies are seen as a potential future for currency issuance and payment models. In fact, according to the 2020 Bank of International Settlements (BIS) survey, 10% of central banks are currently contemplating the issuance of central bank digital currency (CBDC) in the near future, with these central banks located in economies that cover 20% of the global population. Interestingly, central banks

in emerging market economies are taking the lead in accelerating the issuance of CBDC, while those in developed countries are taking a more cautious approach toward transitioning from traditional to digital currencies (Zhou, Wang, & Pan, 2021). As the world becomes increasingly reliant on digital technology, it is evident that digital currencies will have a significant role to play in the future of currency issuance and payment models. This is mainly because the issuance of CBDC is a systemic project that involves not only software, application environment construction, and hardware support, but also the compilation of relevant laws and regulations, and even the adjustment of the organizational structure of financial institutions. Especially for large economies, the impact of issuing a CBDC is a currency reform that needs to be evaluated and promoted very carefully to safeguard the stability of the financial order (Zeng, 2018).

CBDCs are naturally characterized by large data flows and low transaction costs, which means that regulators and financial institutions need to maintain a balance between individual user privacy and information security and fulfilling the proliferation financing of the three "anti" obligations of anti-money laundering, anti-terrorist financing, and anti-WMD (weapons of mass destruction). On the other hand, consumers may be worried about the excessive collection, processing, and use of personal information regarding the use of CBDC, which will affect their willingness to use it. Research has found that providing consumers with privacy feedback, such as when the data was collected, the categories, and access rights, can alleviate consumers' privacy concerns (Ariffin, Mohan, & Goh, 2018; Ilhamalimy & Ali, 2021; Sandra & Shi, 2003). According to a survey conducted by the Internet Society of China, 78.2% of internet users have had their personal identity information leaked, and 63.4% have had their online activity information compromised. Moreover, almost half of the respondents (49.7%) consider this issue to be serious (Investigation Report on the Protection of the Rights and Interests of Chinese Internet Users, 2021). Similarly, research from the Pew Center in the United States shows that 57% of mobile app users refrain from installing any apps due to concerns over inadequate privacy protection for their personal information (Smith, 2018). Therefore, finding a balance between regulation and privacy protection by implementing effective safeguarding measures is crucial for the successful promotion of CBDC.

Currently, research on CBDC is still in its early stages, and scholars have primarily focused on the composition and definition of a CBDC (Chen & Siklos, 2022; Ozili, 2023), as well as its impact on macroeconomic and monetary policy (Auer et al., 2022; Davoodalhosseini, 2022; Li, 2023). However, there has been relatively little research conducted on the micro-level entities impacted by CBDC. Any existing research mainly focuses on financial institutions (Chiu, Davoodalhosseini, Jiang, & Zhu, 2023; Zhou, Huang, & Zhou, 2021) with few studies focusing on individual consumers. Furthermore, despite increased attention being paid to privacy protection issues surrounding CBDC issuance, academic research exploring the relationship between CBDC and privacy protection remains scarce. Based on the above background, this paper constructed a tripartite game model involving consumers, commercial banks, and regulators to explore the impact of privacy protection on the issuance of CBDC. By constructing the tripartite game model, this paper aims to clarify how privacy protection affects the insurance of CBDC and provide a theoretical basis for the privacy protection of CBDC.

This article's innovative contributions lie in three key aspects that distinguish it from previous literature. Firstly, this paper fills a gap in the micro-level research field of CBDC by expanding the study on how it impacts individual consumers. Secondly, it explains why privacy protection regulations for CBDC need to be economically bounded by constructing a tripartite game model that includes consumers, commercial banks and regulators. Thirdly, the model presented in this paper demonstrates how opportunism can hinder the efficient issuance of CBDC and provides an explanation for such inefficiencies. These findings offer valuable insights into formulating effective policies for promoting CBDC issued by central banks.

2. Related Literature Review

2.1. Research on CBDC

The earliest form of digital currency was the "bookkeeping currency", which relied on improved clearing methods within the existing monetary system (Bordo, 2022). This type of digital currency, also known as "electronic cash", required consumers to deposit funds in advance and obtain equivalent electronic cash, which could then be stored on relevant storage devices for later use (Buck, 1997; Kobrin, 1997). While this technology was widely discussed in the last century, it quickly lost popularity with the widespread adoption of credit cards, debit cards, and third-party payment platforms. Today, digital currency primarily refers to cryptocurrencies (such as Bitcoin) that are based on network encryption technology. Depending on their issuers' characteristics, digital currencies can be classified into privately issued digital currencies (private digital currencies) and those issued by central banks (CBDC).

In recent years, the rapid development of private digital currency, especially the massive application of the new financial technology behind it, steadily increases the influence of private digital currency, and may even impact economic and financial operations. Therefore, at present, most regulators around the world have a negative attitude toward private digital currencies (Sun, Yongchao, Kejin, Xuelian, & Chuanxiao, 2019). China even banned all domestic digital currency trading platforms in 2017 and announced that private digital currencies would be banned from direct trading through legal tender.[1] But the rapid development of the internet

1 In 2017, a *Public Notice of the PBC* (People's Bank of China), *the CAC* (Cyberspace Administration of China), *the MIIT* (Ministry of Industry and Information Technology), *the SAIC* (State Administration for Industry and Commerce), *the CBRC* (China Banking Regulatory

means that simply banning it will not completely solve the problems brought by private digital currency. For monetary authorities, dredging is better than blocking. Some exporters believed that using the same or even more advanced technology and design than CBDC is a better solution (Allen, Gu, & Jagtiani, 2022).

CBDC is a digital form of money issued by a central bank. It is a form of digital money that is designed to be a secure, efficient, and cost-effective alternative to traditional forms of money (Scharnowski, 2022), which will have significant implications for financial systems, financial stability, and monetary policy (Auer et al., 2022). At present, the research on CBDC is in the exploratory stage in all countries. There is no clear concept or blueprint for a specific form of CBDC (Yao, 2018). However, several existing digital currency concepts, including China's E-CNY, the UK's Rscoin, Canada's Jasper, Singapore's Ubin, and Sweden's E-Krona, have made it clear that the central banks' digital currencies mainly belong to the M0 and have unlimited legal compensation (Bordo & Levin, 2017). However, Yang and Zheli (2020) believe that CBDC may be limited by the terminal equipment, which would make it difficult to have unlimited legal tender. Therefore, in the legal sense, CBDC is incompatible with the existing definition of currency. Some researchers have suggested that CBDC should be understood as a special creditor's right to the central bank (Bossu, Itatani, & Rossi, 2020).

2.2. Financial Privacy and Financial Regulation

Research indicates that financial privacy information sharing can effectively reduce the occurrence of adverse selection and moral hazard phenomena (Houston, Lin, Lin, & Ma, 2010). Pagano and Jappelli (1993) studied the practical effects of credit information sharing in the credit market, and the results show that the lack of information sharing mechanisms can lead to severe adverse selection, which can exclude borrowers with good credit from the credit market. The establishment of credit information sharing mechanisms can contribute to the growth of credit scale. The higher the level of sharing, the larger the credit scale. From the perspective of CBDC, the financial privacy protection obligation and the three anti obligations are the legal obligations that commercial banks should perform. The financial data and financial privacy protection obligation generated in the process of CBDC circulation correspond to the financial privacy of consumers, which is formed between the equal civil relationship between banks and customers and aims to maintain the inviolable rights of customers' financial privacy. The three anti obligations and anti-tax evasion correspond to the public power of the country, in which the interests of social economic order and financial market security are maintained.

At the same time, from the perspective of global anti-money laundering, the upstream crimes involved in money-laundering are expanding. Even Switzerland, which is famous for its "secret paradise", is actively cooperating with international anti-terrorism actions. The characteristics of CBDC are easy to carry, easy to transfer and relatively anonymous, which also means that if CBDC is not properly regulated, it is very easy to become a criminal paradise. Therefore, when the financial privacy protection obligation generated by CBDC business conflicts with the three anti obligations, these anti obligations should take precedence.

However, if a customer needs to make certain financial privacy concessions for the purpose of maintaining social and economic order with the public power of anti-money laundering, it does not mean that the customer's financial privacy is not protected by law in the process of anti-money laundering. On the contrary, the abnormal development of public power and the excessive shrinkage of private rights will lead to the excessive erosion of public power over private rights, which also violates the goal that, ultimately, public power better protects the realization of private rights. In order to achieve a harmonious balance between the protection of customers' financial privacy rights and the three anti obligations in the CBDC business, we must improve the exercising of customers' financial privacy rights and restrict the excessive expansion of public power over anti-money laundering. The government can obtain customers' financial information based on anti-money laundering power, and the bank can provide customers' financial information to government agencies based on the anti-money laundering obligation. In this process, if the power is improperly exercised without the necessary restrictions, the government may also infringe on customers' financial privacy, and the bank may also violate the financial privacy in the name of anti-money laundering, causing wanton destruction of customers' rights to privacy.

It is not difficult to see that the issue of financial privacy and financial regulation during the promotion of CBDC is not only a balance between privacy rights and public power, but also a balance between privacy and efficiency. A typical example is that emerging economies are more willing to research and issue fiat digital currencies than developed economies and are more concerned about improving the payment efficiency and financial inclusion of fiat digital currencies, whereas developed economies pay more attention to the privacy protection of financial payments in fiat digital currencies and the stability of their financial systems (Khiaonarong & Humphrey, 2022). This is mainly because emerging economies need higher efficiency to improve their economies, while the marginal benefits of this increased efficiency in developed economies are lower than the benefits gained from privacy loss.

For now, on the premise of determining that the private banking business takes the anti-money laundering obligation as the priority, it is also necessary to give customers the right to personal financial privacy protection. It is necessary to set a certain limit for the exercise of public power, provide a certain way for the relief of private

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Commission), *the CSRC* (China Securities Regulatory Commission) *and the CIRC* (China Insurance Regulatory Commission) *on Preventing Risks of Fundraising through Coin Offering* was announced. From the date of release of this Notice, fundraising through coin offering was asked to be banned immediately in China. http://www.pbc.gov.cn/en/3688110/3688181/3712144/index.html.

rights, and use private interests to restrict public power. However, whether the current privacy protection law can effectively respond to the new changes needs in-depth study.

2.3. Financial Privacy and Consumer Behavior

A large number of empirical studies have shown that perceived risk will have a certain impact on consumer behavior. Consumers conceal their true identity information because of the perceived risk, so it can be considered that online identity concealment has an indirect impact on purchasing behavior (Ajzen, 1991). Xu, Teo, Tan, and Agarwal (2009) also believe that privacy protection methods have a significant direct and positive impact on consumers' perceived privacy control and behavioral intention, and indirectly and positively affect consumers' behavioral intention through perceptual control.

User privacy perception not only directly affects consumer behavior tendencies, but also indirectly affects consumer behavior tendencies by influencing risk perception and trust perception. The study found that there is a significant negative correlation between website security and consumer privacy risk (Zhang, Chen, & Lee, 2013). It is important to note that consumers' perception of privacy has a direct impact on their risk perception. When consumers have a higher perception of privacy, their risk perception is also heightened. This, in turn, can negatively impact their behavior toward electronic payment systems if they perceive the risks to outweigh the benefits. Furthermore, it is difficult to establish a sense of trust in mobile electronic payment if consumers have a high perception of privacy, which can also negatively impact their behavior (Xu, Dinev, Smith, & Hart, 2011).

On the other hand, sharing consumer privacy information, particularly with regard to financial privacy, can be beneficial in reducing adverse selection, moral hazard, transaction risk, and the probability of default (Houston, 2003). As a result, some scholars argue that privacy protection should be compromised for the sake of credit information sharing. In other words, disclosing privacy information may be better than protecting it in terms of promoting public interests (Klein, Faratin, Sayama, & Bar-Yam, 2002). Therefore, it can be argued that there is a trade-off between privacy protection and credit information sharing, and finding the right balance between the two is crucial for promoting public interests while also ensuring consumer privacy and trust in electronic payment systems. Awad and Krishnan (2006) and other scholars also believe that consumer information is crucial to the promotion of online consumption, but it is necessary to take into account the way consumers collect and use private information. Only when consumers recognize the ways in which e-commerce enterprises collect and use private information, their attention to private information will decline, and e-commerce enterprises can maximize their benefits.

Defining the boundaries of consumer privacy and balancing the relationship between privacy protection and information sharing are of great significance to the implementation of CBDC. Only by protecting consumer privacy can we promote the use of CBDC, and only by balancing privacy protection and information sharing can we apply effective financial supervision and ensure the healthy development of CBDC.

3. Construction and Analysis of the Trilateral Game Model

3.1. Model Settings

Although various countries have strengthened their research on legal tender digital currencies, and some countries have even begun to explore the issuance, circulation, and institutional arrangements of legal tender digital currencies, most countries have not proposed substantive and specific issuance plans. After years of research and discussion, various countries have agreed that there are generally two types of issuance mechanisms for CBDC: a unitary credit issuance mechanism in which the central bank directly issues digital currency to the public, and a binary credit issuance mechanism based on the "central bank–commercial bank" model. The former provides direct circulation and maintenance services, while the latter follows the current paper money circulation model where CBDC enters circulation through commercial banks. Specifically, the binary credit issuance mechanism establishes a clear role for each participant in the operation of CBDCs. As the first tier, the central bank takes a central position and manages the CBDC quota, issuance and cancellation, as well as cross-institutional interconnection and CBDC wallet ecosystem. The central bank is also responsible for supervising and managing CBDC exchange and circulation services. Commercial banks, designated as the second tier, become the operating institutions responsible for providing CBDC exchange and circulation services. They must meet certain requirements related to asset size, profitability, risk management ability, cash service ability, payment service ability, and technological innovation ability. The designated operating agency opens different types of CBDC wallets for users based on customer information. Under this mechanism, the central bank does not directly exchange CBDC with the public. Instead, it first exchanges CBDC with designated operating institutions, such as commercial banks, who then exchange it with the public. To ensure stability, the operating institution needs to pay a 100% reserve to the central bank, and the exchange process follows a 1:1 conversion process. This mechanism has several advantages, including better integration of the CBDC into the existing financial infrastructure and the avoidance of narrow banking. Furthermore, it establishes a clear division of responsibilities among participants, ensuring effective management and supervision of the CBDC ecosystem. The binary credit issuance mechanism of the CBDC is illustrated in Figure 1. Therefore, our model mainly discusses CBDC under a binary credit issuance mechanism.

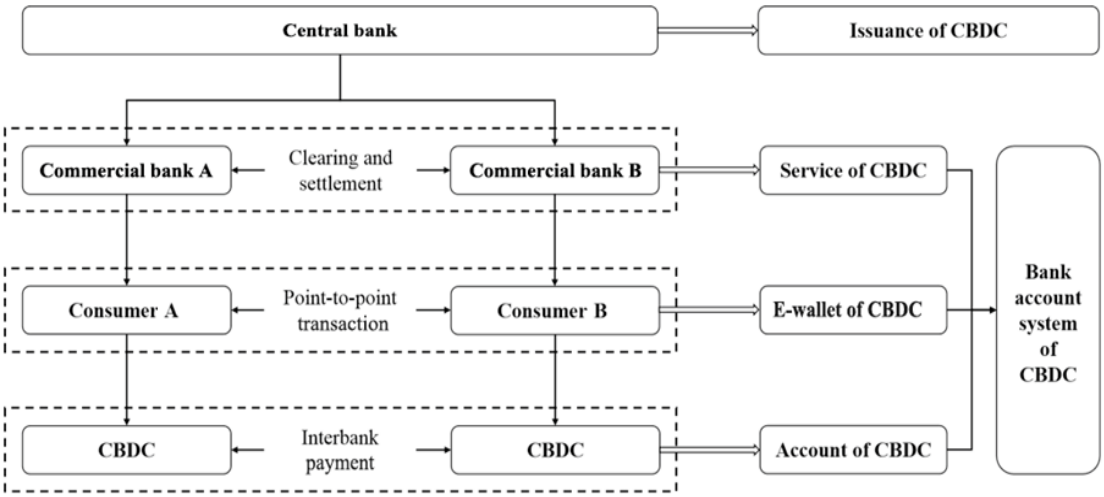

Figure 1. Binary credit issuance mechanism of CBDC.

This model assumes that there are only three parties involved in the process of CBDC issuance – the central bank, commercial banks and individual consumers. The central bank first decides the issuance of the CBDC, and then the commercial banks follow up and participate, and consumers decide whether to use it. The reason for this setting is that the issuance of CBDC is the top-level design, which is decided by the central bank. Commercial banks and consumers can only decide how to follow up and participate. However, this study regards the consumers' use behavior as one of the key factors for the success of CBDC issuance. This is because in the process of CBDC promotion, no matter how hard the central bank and local government try to promote it, the key factor that ultimately determines the success of digital currency is whether there is a real transaction and payment demand. However, considering the "rational" characteristics of consumers themselves, this subjective initiative is not always at the highest point. It will be affected by the central bank and commercial behavior. This paper uses the "degree of privacy transfer" to measure the size of this subjective initiative.

3.2. Game Process

The whole tripartite game process of CBDC is shown in Figure 2.

In the first step, the central bank has decided to issue CBDC, which needs investment I_{cb}, such as capital and manpower. At the same time, the central bank requires consumers to provide privacy data p for the use of CBDC. By analyzing privacy data p, the central bank can better grasp the macro and micro economic situation, and thus gain benefits $B(p)$. In the second step, after the issuance of CBDC, the commercial banks observe the input I_{cb} of the central bank. For compliance and operational needs, commercial banks can ask the central bank to transfer some CBDC data, and therefore obtain relevant income $\theta B(p)$ and decide their own input I_b. In the third step, consumers observe the central bank's requirements for privacy data p, and the process of privacy transfer has produced a negative utility for consumers $C(p)$. However, CBDC also brings consumers a better experience, such as portability. After weighing the advantages and disadvantages, consumers decide their demand $D(p)$, which is also the market's demand, for digital currency.

The negative utility $C(p)$ generated in the process of privacy data p transfer is only related to the size of the amount of private data provided. We assume that the negative utility $C(p)$ will increase with the increase of the transfer of privacy $C'(p) > 0$ and meet the characteristics of increasing marginal cost $C''(p) > 0$. Regarding the demand for CBDC $D(p)$, we assume that $D(p)$ is the inverse function of p. Its economic meaning is that consumers prefer CBDC that requires less privacy data p. In other words, the less privacy data the central bank needs, the better it is for consumers. θ reflects the bargains between commercial banks and the central bank. Commercial banks want the central bank to share CBDC data as much as possible, while the central bank wants to reduce the amount of data shared with commercial banks for regulatory reasons $\theta \in [0,1]$.

This model assumes that the game process has only one stage, and there are only two possible outcomes – failure or success. The factor used to judge the success or failure is whether the final use of CBDC meets D^*, which is the expectation of the central bank. Only when the demand for CBDC is larger than the expectation of the central bank, $D(p) \geq D^*$, will the issuance of CBDC be successful. According to the above analysis, the less private data the central bank asks for, the greater the $D(p)$ will be. However, when p is small, it is difficult to encourage the central bank to issue the CBDC. Therefore, there is an incentive threshold, M_1, for the central bank. Only when $B(p) - I_{cb} \geq M_1$ will the central bank have enough power to issue the CBDC.

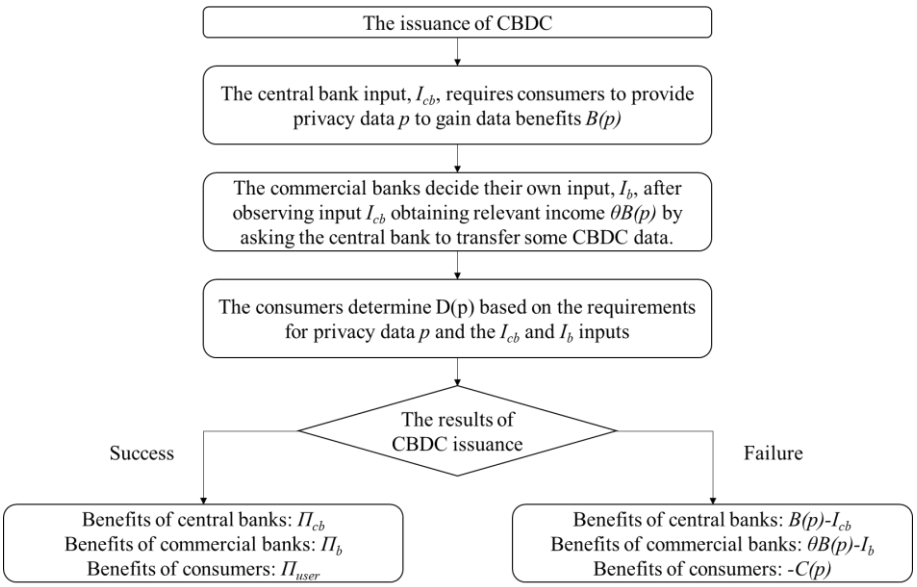

Figure 2. Tripartite game process of CBDC.

For commercial banks, the issuance of CBDC is both an opportunity and a challenge. The new payment channel and the reduction of operating costs (the reduction of cash management and escort cost) are not of high economic value, while the data value brought by CBDC is much more important. So, there is also an incentive threshold M_2 for commercial banks. If the value of the data shared by central banks covers its cost, that is $\theta B(p) - I_b \geq M_2$, commercial banks will have enough power to participate in the issuance of CBDC.

Therefore, the successful issuance of CBDC is actually the result of the tripartite game, that is $D(p, I_{cb}, I_b) = D^*$. The economic implication of the result is that the excessive squeeze of public power on private rights and the demand for too much privacy data may lead to consumers reducing their use of CBDC, or even giving up the use of CBDC. I_{cb}, I_b reflects the investment of resources. The more resources invested, the better the development of CBDC and the better the user experience. On the other hand, if the user experience of CBDC is particularly good, customers will be willing to share more privacy data.

3.2.1. Participant Decision

This model assumes that the probability of successful issuance of digital currency is $P = \alpha(I_{cb})\beta(I_b)\gamma(p)$, where $\alpha(I_{cb})$, $\beta(I_b)$ and $\gamma(p)$ are the respective probability functions of the central bank's investment I_{cb}, commercial banks' investment I_b, and consumers' privacy data p. From the definition function of the success of digital currency issuance, we can see that the central bank, commercial banks and consumers are indispensable, and if one party participates negatively, the promotion of CBDC will suffer setbacks. Regarding $\alpha(I_{cb})$, $\beta(I_b)$, and $\gamma(p)$, this model assumes the following properties:

$$\alpha(I_{cb}) \in [0,1]、\alpha'(I_{cb}) > 0,\ \alpha''(I_{cb}) < 0 \quad (1)$$

$$\beta(I_b) \in [0,1]、\beta'(I_b) > 0,\ \beta''(I_b) < 0 \quad (2)$$

$$\gamma(p) \in [0,1]、\gamma'(p) < 0,\ \gamma''(p) > 0 \quad (3)$$

In Equations 1 and 2, $\alpha'(I_{cb}) > 0$, $(I_b) > 0$ presents that the probability of success continues to increase with the continuous increase of investment, but the probability of success marginally decreases, which could be written as $\alpha''(I_{cb}) < 0$, $\beta''(I_b) < 0$. In Equation 3, $\gamma'(p) < 0$ argues that the more private data requested, the lower the probability of success, and $\gamma''(p) > 0$ presents that consumers' aversion to privacy data requests is marginal and increasing.

If the issuance of CBDC is successful, the central bank, commercial banks and consumers will gain benefits Π_{cb}, Π_b and Π_{user}, otherwise, the income of all three parties is 0. Based on the above analysis, the probability distribution of the expected returns for the three parties is shown in Table 1.

Table 1. Probability distribution of expected returns of participants.

Participant	**Probability of success: $\alpha(I_{cb})\beta(I_b)\gamma(p)$**	**Probability of failure: $1 - \alpha(I_{cb})\beta(I_b)\gamma(p)$**
Central bank	$\Pi_{cb} + B(p) - I_{cb}$	$B(p) - I_{cb}$
Commercial banks	$\Pi_b + \theta B(p) - I_b$	$\theta B(p) - I_b$
Individual consumers	$\Pi_{user} - C(p)$	$-C(p)$

Based on this, the final benefits generated by each party are:

$$U_{cb} = \alpha(I_{cb})\beta(I_b)\gamma(p)[\Pi_{cb} + B(p) - I_{cb}] + [1 - \alpha(I_{cb})\beta(I_b)\gamma(p)][B(p) - I_{cb}] = \alpha(I_{cb})\beta(I_b)\gamma(p)\Pi_{cb} + B(p) - I_{cb} \quad (4)$$

$$U_b = \alpha(I_{cb})\beta(I_b)\gamma(p)[\Pi_b + \theta B(p) - I_b] + [1 - \alpha(I_{cb})\beta(I_b)\gamma(p)][\theta B(p) - I_b] = \alpha(I_{cb})\beta(I_b)\gamma(p)\Pi_b + \theta B(p) - I_b \quad (5)$$

$$U_{user} = \alpha(I_{cb})\beta(I_b)\gamma(p)[\Pi_{user} - C(p)] + [1 - \alpha(I_{cb})\beta(I_b)\gamma(p)]C(p) = \alpha(I_{cb})\beta(I_b)\gamma(p)\Pi_{user} - C(p) \quad (6)$$

3.3. Equilibrium Analysis

The behaviors of central banks, commercial banks and consumers have a sequence, and all three parties can master the reaction functions of other participants and know that their own behaviors will affect the other participants. Therefore, based on the possible behavior of commercial banks and participants, the central bank will use the "reverse induction" to make decisions to determine the investment I_{cb} they make, the privacy data p they request, and the amount of data θ they share with commercial banks. Commercial banks make decisions based on the the central bank's input I_{cb} and the shared data p. Consumers observe the input of the central bank and commercial banks and the requirements for privacy data to determine their demand $D(p, I_{cb}, I_b)$.

However, $D(p, I_{cb}, I_b)$ and I_b are not carried out at the same time, and the consumers' demands are difficult to determine. As soon as the information for I_b、 p and θ is released, consumers and commercial banks will be informed. Based on this, the utility of commercial banks can be obtained by the first derivative:

$$\frac{\partial U_b}{\partial I_b} = \alpha(I_{cb})\beta'(I_b)\gamma(p)\Pi_b - 1 \quad (7)$$

The utility of consumers is obtained by first derivative:

$$\frac{\partial U_{user}}{\partial p} = \alpha(I_{cb})\beta(I_b)\gamma'(p)\Pi_{user} - C'(p) \quad (8)$$

For the central bank, the first derivative is obtained:

$$\frac{\partial U_{cb}}{\partial I_{cb}} = \alpha'(I_{cb})\beta(I_b)\gamma(p)\Pi_{cb} - 1 \quad (9)$$

$$\frac{\partial U_{cb}}{\partial p} = \alpha(I_{cb})\beta(I_b)\gamma'(p)\Pi_{cb} + \theta B'(p) \quad (10)$$

Further, the utility of consumers, commercial banks and the central bank can be derived from the second derivative:

$$\frac{\partial^2 U_{user}}{\partial^2 p} = \alpha(I_{cb})\beta(I_b)\gamma''(p)\Pi_{user} - C''(p) \quad (11)$$

$$\frac{\partial^2 U_b}{\partial^2 I_b} = \alpha(I_{cb})\beta''(I_b)\gamma(p)\Pi_b \quad (12)$$

According to the previous assumptions, we could say that $\frac{\partial^2 U_{user}}{\partial^2 p} < 0, \frac{\partial^2 U_b}{\partial^2 I_b} < 0$. Therefore, as long as the sub-game between commercial banks and consumers has an equilibrium, the equilibrium solution of the trilateral game will also exist. The above results show that the expectation function of commercial banks and consumers is concave. According to the Nash equilibrium restraint, if a sub-game has an equilibrium state, the whole tripartite game has an equilibrium. The second order guideline for the utility of the central bank can be obtained as follows:

$$\frac{\partial^2 U_{cb}}{\partial^2 cb} = \alpha''(I_{cb})\beta(I_b)\gamma(p)\Pi_{cb} \quad (13)$$

$$\frac{\partial^2 U_{cb}}{\partial^2 p} = \alpha(I_{cb})\beta(I_b)\gamma''(p)\Pi_{cb} + \theta B''(p) \quad (14)$$

The result shows that, although consumers can better mobilize the enthusiasm of the central bank on the issuance of CBDC by providing more private data, consumers will not take the initiative. Similarly, commercial banks will not actively increase their investment, although increasing their investment in digital currency can improve the user experience. The economic implication of this is that in actual operation, commercial banks and consumers may engage in opportunistic behavior. Specifically, commercial banks and consumers may expect the central bank to increase its investment, leading to commercial banks avoiding collaboration and consumers being uncooperative. Such tendencies would result in the inefficient issuance of CBDCs.

4. Conclusion and Recommendations

The implementation of CBDCs is a complex process that involves multiple stakeholders, including consumers, commercial banks, and regulators. In order to ensure successful adoption of CBDCs, it is important to consider factors such as safety, convenience, and regulatory difficulties for all parties involved.

This paper explores the impact of privacy protection on the issuance of CBDCs by constructing a tripartite game model that includes consumers, commercial banks, and regulators.

The results of the model suggest that privacy protection is critical to ensuring successful adoption of CBDCs. Central banks must strike a balance between protecting user privacy while also regulating usage and ensuring convenience for users. However, due to opportunistic behavior by both commercial banks and consumers during this process, negative reactions are possible.

Based on the above research conclusions, this paper puts forward the following recommendations: As central banks play a critical role in promoting the adoption of CBDC, firstly, they should encourage commercial banks

to participate in the issuance of CBDC by mobilizing their enthusiasm. This can be done through appropriate data sharing, which will help commercial banks understand the potential benefits of CBDC. By sharing relevant data, the central bank can motivate commercial banks to participate in the issuance of CBDC. Secondly, the central banks should supervise the involvement of commercial banks in promoting the use of CBDC. This can be done through window guidance and other means. By providing clear guidelines and support, central banks can ensure that commercial banks are actively promoting the use of CBDC and are following the regulations. Thirdly, central banks should also focus on consumer propaganda and management of expectations. This means helping consumers fully understand the positive significance of using CBDC, including efficiency, convenience, and security. At the same time, the central banks should ensure that consumer privacy is protected. By doing so, consumers can fully enjoy the benefits of CBDC while feeling confident that their personal information is safe.

Commercial banks, as the most important financial intermediaries, will play a significant role in the operation of CBDC, providing exchange and other services to the public, especially under the binary credit issuance mechanism. Commercial banks should consider the issuance and application of CBDC in the overall transformation of bank digitization. They should also make corresponding adjustments and arrangements to ensure capital investment, restructure organizations, and evaluate incentives. Furthermore, commercial banks need to study the policies and regulations, development planning, and practical applications of CBDC, and plan for relevant work, such as channel layout, product development, scenario construction, customer marketing, business promotion, and risk control upgrading, in advance. Commercial banks should also enrich the supply of CBDC financial services and strengthen inclusive finance. They should develop structured inclusive financial products that meet the needs of different regions, promoting the wider and deeper integration of CBDC into the local economy and serving local economic development. In summary, commercial banks must embrace digital transformation and adapt to the changing landscape of the financial industry to remain competitive and provide innovative financial services to their customers.

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