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A study of the economic impact of Central Bank Digital Currency under global competition

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ABSTRACT
From both theoretical and practical perspectives, we examine the global development and competition of digital currencies, and investigate the design of China's central bank digital currency (CBDC). Moreover, on the basis of correcting shortcomings in the existing literature, we undertake a quantitative analysis of the economic impact of the issuance of DC/EP based on a four-sector DSGE model. The results demonstrate that the substitution effect of DC/EP on bank deposits is limited, while the unit impact can enhance the economic growth rate by 0.15% and the overall economic effect is positive, at the same time it reduces the leverage ratio to a certain degree, which is conducive to reducing systemic financial risk. Therefore, we contend that China should accelerate the research and development of DC/EP and launch pilot schemes to promote DC/EP. Moreover, China should actively participate in the drafting of international regulations for digital currencies, selectively liberalize the jurisdiction of overseas nodes, jointly establish an integrated digital infrastructure for future generations.

KEYWORDS
Central bank digital currency; global stablecoin; crypto digital currency; economic impact

In the wake of the rapid growth of the digital economy, the digitization of currency, as the basic infrastructure and core variable of modern economic finance, has become the trend of historical development. In fact, with the integration of modern digital technologies such as the internet, artificial intelligence, and blockchain amongst others, the concept of money itself is becoming increasingly vague, showing a tendency of redefinition. In summary, there are three categories of digital currencies that have potential impacts on the international monetary and financial system: the first is encrypted digital currency represented by Bitcoin and Ethereum, the second is global stablecoin as represented by Libra and USDT, finally the third kind is digital currency directly issued by central banks (Central Bank Digital Currency, CBDC).

In the face of the new circumstances, questions and challenges staked out by competition between global digital currencies, the Central Committee of the Communist Party of

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China with Comrade Xi Jinping at its helm attaches great importance to the development of China's digital currency. In the 21st issue of *Qiushi* Journal in 2020, General Secretary Xi Jinping proposed that China actively participate in the formation of international regulations on areas such as digital currency and digital taxation. The *Proposal of the CENTRAL Committee of the Communist Party of China on Formulating the 14th Five-year Plan for National Economic and Social Development and the Long-range Objective for the year 2035* adopted in October 2020 clearly specified that the development of digital currencies should be steadily promoted. At present CBDC is still in the R&D and pilot stage, as there are still many issues to be studied and proofed. On this basis, we examine from both theoretical and practical perspectives the development of digital currencies globally, and investigate the design of Chinese CBDC, or digital currency/electronic payment (DC/EP). Moreover, on the basis of correcting shortcomings in the existing literature, this paper undertakes a quantitative analysis of the economic impact of the issuance of DC/EP based on four-sector DSGE model.

1. The state of competition in Global Digital Currency Development

The development of CBDC is closely related to the impact of cryptocurrency and global stablecoin on national monetary and financial sovereignty. The first cryptocurrency, Bitcoin, was born in 2009 in the aftermath of the Global Financial Crisis (GFC). Its basic premise is to utilize algorithmic trust to substitute for the centralized trust model of traditional finance (Tong 2018). However, Bitcoin is non-Turing-complete, and in terms of practical value, it is merely a blockchain-based transfer system (Satoshi Nakamoto 2008). In response to some of Bitcoin's drawbacks – such as its finite supply – Ethereum, a state machine for trading services, was created in 2014. The emergence of Ethereum led to a boom in Initial Coin Offerings (ICOs), a new method of financing, investors in ICO do not receive traditional proof of investment such as stocks, but rather a certain amount of the cryptocurrency in question. Despite the gradual rise of Security Token Offerings (STO) as ICO face regulatory dilemmas and issues with regard to their business model, in essence STO still belong within the framework of ICO.

The cryptocurrency exchange plays a central role in the entire ICO process, in that the relevant cryptocurrency bodies publish white papers on the cryptocurrency exchange and complete primary market financing, and after that secondary market trades of the cryptocurrency can be made on the exchange. Although ICO have changed the form of investment and financing, they have not changed its substance given that the majority of ICO based on cryptocurrencies fulfill the criteria of profitability, risk, standardization, and are tradable and redeemable they are therefore within the scope of securities (Sun Guofeng and Chen Shi, 2019). At the same time, cryptocurrency cannot perform monetary functions such as acting as a standard of value or medium of exchange and so it cannot constitute currency in the real sense of the word (Zhang Liqing and Wu Tong, 2019). However, in actual fact, not all countries regulate cryptocurrencies within the framework of securities. Figure 1 presents the comparison of ICO and IPO processes, we can see ICO processes face much looser regulation than IPO, which may lead to a greater level of risk.

The basic regulatory models of ICO and cryptocurrency exchanges in mainstream countries can be divided into two types: the first type is a total ban on ICO and

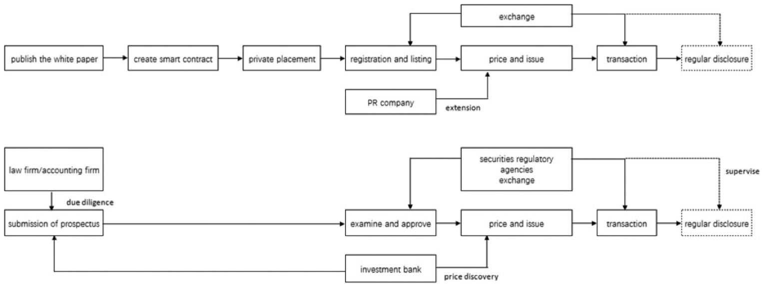

Figure 1. Comparison of ICO (top) and IPO (bottom) processes.

cryptocurrency exchanges, the countries representative of this model are China and South Korea. In September 2017, the people's Bank of China along with seven other ministries defined ICO as an act of unlawful public financing which had yet to receive authorized, and further refused to allow cryptocurrency exchanges to provide related services in mainland China. Subsequently, the Korean Financial Services Commission stated that ICOs violated the Capital Markets Law and banned them. The second model is to incorporate ICOs and cryptocurrency exchanges into the existing financial regulatory system according to the principle of substance over form. According to the degree of regulatory control placed upon cryptocurrencies, this model can be further divided into 'Penetrating Regulation' as seen in the United States and Japan, or 'Light-Touch Regulation' as applied in Switzerland and Singapore. The various regulatory frameworks adopted toward cryptocurrencies as represented by China and the United States reflect the different governance frameworks and regulatory approaches (Wu Tong et al. 2020).

Global stablecoin is a kind of digital currency that achieves price stability by anchoring mainstream fiat currencies on the blockchain. Due to the cross-border nature of digital currency circulating on the blockchain, it is called 'global stablecoin'; the principal issuing bodies of such currency are commercial organizations, which utilize the blockchain and other digital technologies to increase trust, as such in essence stablecoin falls within the remit of commercial credit. With regard to global stablecoin, the most influential organization is the Libra Association, which is mainly composed of the world's top tier technology enterprises, but China's technology companies (such as Tencent, Alibaba, JD.COM, ByteDance, Meituan, etc.) are excluded. In terms of mortgaged assets, Libra includes both a mortgage model based on single currencies such as the US dollar, the euro, the British pound, and the Japanese yen, as well as a mortgage model based on

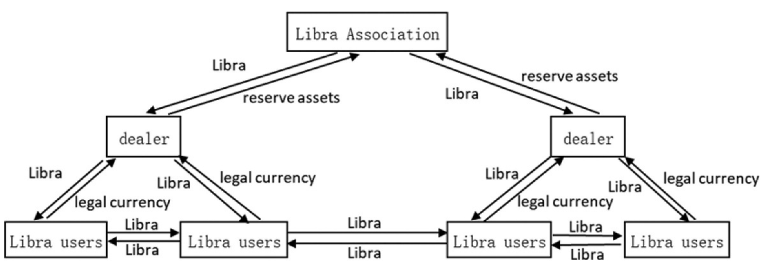

Figure 2. Mechanism the Libra economic system operates.

these currency baskets, with renminbi assets also excluded (Wu Tong and Guo Jianluan, 2019).

Figure 2 presents the operating mechanism of the Libra economic system, we can find that Libra's two-tier economic system has a degree of similarity with the current 'Central Bank-Commercial Bank' binary currency delivery system: the Libra Association is equivalent to central banks, whereas dealers are equivalent to commercial banks. However, unlike the account-based 'Central Bank-Commercial Bank' system, Libra is a token-based economic system that implements peer-to-peer transfers between users, which essentially constitutes a Semi-DeFi (decentralized finance) model (Wu Tong, 2020).

The final determination as to whether Libra will ultimately be issued and as to the formulation of international standards set for global stablecoin is in the hands of the G7 central bank with the Federal Reserve at its core, along with a few other international financial organizations as outlined below. For example, the Financial Stability Board (FSB) is responsible for the development of global stablecoin regulatory policy recommendations along with the development of a cross-border payment roadmap. The Committee on Payments and Market Infrastructures (CPMI), which is attached to the Bank for International Settlements (BIS), plays a central role in standard-setting for the payment and clearing infrastructure of global stablecoins. The Basel Committee on Banking Supervision (BCBS), which is part of BIS, is responsible for prudential supervision of the exposure of commercial banks to crypto assets and related services. The Financial Action Task Force (FATF) is primarily responsible for the work of anti-money laundering/counter-terrorism financing (AML/CTF) standards involved in global stablecoins. The International Monetary Fund (IMF) is responsible for assessing the impact of global stablecoins on the monetary sovereignty of member states. Finally, the International Organization of Securities Commissions (IOSCO) is responsible for assessing the impact of proposals about global stablecoin on stock market regulators (Wu Tong and Li Ming, 2019).

In April 2020, the Libra Association released the Libra White Paper 2.0, which made major changes, including abandoning the consortium blockchain in favor of the public blockchain, reflecting a certain degree of consensus between the Libra Association and European and American financial regulators. There have been increasing indications of late that it is only a matter of time before Libra is launched, and this poses a significant challenge to the monetary and financial sovereignty of emerging economies including China.

In response to digital financial innovation and improving the effectiveness of monetary policy, in recent years many central banks have begun to develop and pilot CBDC, CBDC is the first rung on the ladder to digitizing currency. According to the working report on CBDC released in January 2020 by the Bank for International Settlement (BIS), which surveyed 21 developed economies and 45 emerging economies around the world, at least 80% of central banks surveyed stated that they were actively studying CBDC, while 30% of central banks indicated that they would issue CBDC in the short to medium-term future.

For example, the Monetary Authority of Singapore (MAS) launched the Union project to test and verify the digitization of the Singapore dollar in 2016. Canada launched its CBDC pilot project CAD-Coin in 2016. The Bank of England developed the CBDC prototype system RSCoin in 2016. In the same year, the Bank of the Netherlands conducted the DNB Coin test; 2016 also saw Japan and the European Central Bank launching the Stella project aimed at enabling cross-border payment. Sweden launched the E-krona beta project in 2020. Before the outbreak of the COVID-19 pandemic, the Federal Reserve and the US Treasury Department made clear that they would not issue CBDC. However, the outbreak of the COVID-19 pandemic made the United States' monetary and financial realize the advantages of CBDC in terms of monetary impact on the real economy, as such they switched toward considering the issuance of CBDC, however they have not realized any specific proposals or details of the project, far less carried out research and development.

The digital currency issued by the People's Bank of China has been christened 'DC/EP' (Digital Currency/Electronic Payment), at the current stage it is positioned for use in retail payment, it is currently the global frontrunner in research and development, which can be divided into three stages. The first stage is the early phase preparatory stage of which the major milestones have included: PBoC set up the CBDC special task force to investigate its potential in 2014; PBoC made two rounds of revisions to its prototype scheme for issuing CBDC in 2015; PBoC further made clarifications to the strategic objectives of the issuance of CBDC in January 2016; PBoC further confirmed that the digital bills trading platform will be the setting for the pilot of CBDC and started the closed development of the digital bill trading platform in November 2016; testing of the digital bank acceptance bills platform was held to be successful in February 2017; the CBDC Research Institute was formally established in May 2017.

The second phase is the steady development phase, the notable events in this stage have been as follows: the Gold and Silver Bureau of PBoC were tasked to strongly promote the research and development of CBDC in 2018; the CBDC Research Institute established the wholly owned Shenzhen Fintech Co., Ltd in June 2018; the CBDC Research Institute cooperated with Nanjing municipality, Nanjing University, Jiangsu Bank and Nanjing branch of PBoC to establish the Nanjing Fintech Research and Innovation Center for use as a model base; the CBDC Research Institute united with a Suzhou-based construction company (苏州高铁新城国有资产经营管理有限公) through Shenzhen Fintech Co. Ltd. to establish the Yangtze River Delta Fintech Co., Ltd in March 2019. This provides the organizational and material basis for CBDC.

The third stage is to accelerate the R&D and pilot stage, the notable events in this stage have been as follows: work began to accelerate R&D of digital RMB in the second half of 2019, facing the increasingly fierce competition with regard to global stablecoin; the State Council officially approved the R&D of digital RMB in July 2019, and the PBoC organized other market players (the 'big four' commercial banks, namely Bank of China, China Construction Bank, Industrial and Commercial Bank of China and Agricultural Bank of China; the 'big three' telecommunications companies, China Mobile, China Unicom and China Telecom; along with some Internet giants such as Tencent and Alibaba) to begin distributed R&D of digital RMB, moreover to give priority to pilot projects in Suzhou, Shenzhen, Xiongan, Chengdu and during the 2022 Winter Olympics; 50% of travel subsidies by government departments were granted in the form of digital RMB in Xiangcheng District of Suzhou City; Luohu District, Shenzhen City launched a pilot project of digital RMB, issuing 10 million yuan which could be spent at 3389 different businesses within the district with no threshold on spending.

In addition, with regard to CBDC international standards, in January 2020 six central banks set up the CBDC Joint Working Group to promote the arrival of and interoperability with CBDC (the banks concerned included the European Central Bank, the Bank of Japan, the Bank of England, the Bank of Canada, the National Bank of Switzerland and the Bank of Sweden); subsequently, the Federal Reserve joined the CBDC Joint Working Group. The CBDC Joint Working Group and BIS jointly released the report 'Central Bank Digital Currency: Foundational Principles and Core Features', which put forward the three principles of 'No harm', 'Coexistence' and 'Innovation and Efficiency' in October 2020. At present, the CBDC Joint Working Group has not allowed a developing country to join, in essence reflecting financial capitalism's attempt to monopolize the emerging field of digital currencies. China is the world's second largest economy and the largest developing country, at the same time it leads the field to a certain extent in R&D and testing of CBDC, the CBDC Joint Working Group's refusal to include China has caused the organization to lack global representativeness, and further embodies the exclusion by capitalist countries (with the United States as representative), of China in international standard setting.

In fact, the relationship between CBDC and global stablecoin is not just a simple competitive relationship, but rather a trend toward integration has emerged. At present, digital currency is the predominant area around which competition in international digital finance is intensifying, with the dollar, euro, RMB and other units of account in the process of forming Digital Currency Areas (DCA). CBDC is at the heart of DCA, while global stablecoin remains on the peripheries. In the Libra White Paper 2.0 released in April 2020, central banks can issue their own country's CBDC directly on the Libra network, at its core Libra's multi-currency stablecoin LBR is based on smart contracts which designate CBDC on the Libra network according to their weighted distribution. The base source of credit in DCA is sovereign credit, but in terms of expanding the credit system, the focus relies on commercial credit, this embodies the public–private partnership mechanism of digital currency. As China has been excluded from setting of CBDC standards and interoperability, it will be forced to further accelerate implementation of CBDC in order to make up for the relative disadvantages this imposes on China's strategy.

2. The mechanism of Central Bank Digital Currency: taking China as an example

Central banks have begun to accelerate the development and testing of CBDC since 2019. To summarize, broadly there are ten major reasons for this phenomenon:

1. CBDC can improve the competitiveness, efficiency and resilience of payment systems in the face of increasingly concentrated levels of payments in the hands of a few Internet giants.
2. CBDC helps to advance financial digitization and inclusive finance, particularly in developing countries where the financial system is underdeveloped and many citizens do not have bank accounts.
3. CBDC can greatly reduce the issuance and transaction costs of the monetary base, improve the efficiency of M0 circulation and the position of central bank currency.
4. CBDC can realize the full cycle of M0 data recording and tracking, improve the

accuracy of currency issuance, and prevent and control financial risks caused by shadow banking.

5. CBDC can use existing digital marketing channels to achieve universality and ubiquity to provide a complete ecosystem for digital-technology-based economic and financial activities (Wu Tong, Li Jiaqi and Chen Mingyu, 2020).
6. CBDC is better adapted to the development of the contactless economy, which is significantly more hygienic. For example, the PBoC allocated 4 billion yuan of new banknotes to the emergency in Wuhan in February 2020, these notes had to be disinfected and stored for two weeks prior to issuance, reducing the efficiency of the currency issuance.
7. CBDC can make national currency a more attractive means of payment, better suited to the competition of international currency within the paradigm of the digital economy; blockchain as the underlying technology of the clearing and settlement system helps to break the hegemony of the US dollar to a certain extent.
8. CBDC can realize a closer integration of monetary and fiscal policy, to achieve a more efficient macro-policy regulatory system.
9. CBDC can better protect citizens' data rights and the security of China's data sovereignty. This requirement has become even more urgent after the Fourth Plenary Session of the 19th CPC Central Committee in 2019, which officially proposed the inclusion of data as one of the essential factors of production.
10. In the long-term CBDC may enrich and improve monetary policy. If CBDC interest is calculated, it will create a new price-based monetary policy tool, offering the opportunity to solve issues within the traditional framework such as obstacles in transmission, difficulties in counter-cyclical regulation, currency shifting from virtual to real and failings in management of policy expectations (Yao Qian, 2018; Yao Qian, 2019).

In reality, of the reasons to promote CBDC outlined above, there is a clear differentiation in the timescales post implementation. Among them, in the short term, points 1 to 6 can play a more immediate role in the aftermath of the launch of CBDC. For example, China's cash stock stood at about 7 trillion yuan by 2018, calculating according to an issuance cost of 1%, it is estimated that the issuance cost of this is about 700 billion yuan. After the CBDC is completed, the marginal cost will be almost zero. Moreover, as the speed of CBDC is not lower than that of third-party payment, in the event that the total amount of M0 does not change, it can improve the speed of capital flow, thereby enhancing the central bank's monetary position (Wu Tong, Li Jiaqi and Cheng Mengyu, 2020). As another example, CBDC can be based upon an unspent transaction outputs model (UTXO) to achieve full cycle data recording and tracking, improve the effectiveness of monetary policy and improve the ability to control systemic financial risks. These are all policy goals which are relatively easy to achieve in the short term.

Whereas, with regard to policy objectives 7–10, CBDC is merely one of the conditions that help contribute to these goals, the ultimate realization of the objective depends on a variety of factors, such as the issue of internationalizing digital RMB. The internationalization of digital RMB, falling under the scope of internationalizing traditional RMB, increases the complexity of certain factors such as the technology and international standards required; it is a complex problem affected by the interplay of many multifaceted factors. The level of acceptance of digital RMB by foreign entities, the convertibility of China's Capital Financial Accounts, China's exchange rate setting mechanism, the robustness of the digital RMB system itself as well as the mechanism for liberalization of overseas nodes will all have a significant impact on this issue (Wu Tong 2018). The mechanism of CBDC needs to be established on the principle of technological neutrality with realizing its policy objectives as a benchmark.

In addition to the achievement of policy objectives as a benchmark for the CBDC mechanism, there is also a need to consider how to prevent and control potential risks. Taken together, there are three potential risks to CBDC: firstly, the risk of a wide-scale run on bank savings by CBDC. CBDC is essentially the liability of PBoC, with a credit rating higher than that of commercial bank savings, and when savers distrust the commercial bank that they make deposits in, or distrust the entire commercial banking system, they will select CBDC (Broadbent, B., 2016). Secondly, when considering CBDC interest, although a new price-based monetary policy instrument may be created in the long term, it is likely that there will be uncertainty in existing monetary policy instruments and transmission mechanisms in the short term. Thirdly, CBDC may provide a new legal deposit interface for cryptocurrencies such as Bitcoin, which will have an impact on cross-border capital flows and impact capital regulation policies (Wu Tong, Li Jiaqi and Chen Mengyu, 2020). In fact, the US dollar stablecoin such as USDT which have already been issued have confirmed the impact on cross-border capital flows (J. Griffin & A. Shams, 2019).

At present, there is scarce little research with regard to the principle of the CBDC mechanism. The report issued jointly by the CBDC Joint Working group and BIS set out three principles for CBDC in October 2020: first, the 'No Harm' principle, that CBDC should support the achievement of public policy objectives and should not interfere with or impede the ability of central banks to fulfil their responsibilities to maintain monetary and financial stability. Second, the principle of 'Coexistence', that is to say, CBDC should coexist with existing cash and bank accounts. Third, the principle of "Innovation and Efficiency", that is to say, CBDC should promote innovation and improve efficiency in society as a whole. Despite the fact that the three principles of CBDC offer a certain level of meaningful guidance, however they are too broad, and lack practicality. In addition, to prevent CBDC runs on commercial bank savings, Kumhof and Noone (2018) propose four core principles:

(1) CBDC should pay an adjustable interest rate;
(2) CBDC and bank reserves are two distinct systems, the two are not convertible into one another;
(3) There is no guaranteed convertibility of bank deposits to CBDC on demand;
(4) Central banks only issue CBDC based on eligible securities.

However, in actual fact these four principles are by no means necessary, and include a certain degree of contradiction (Tong et al. 2020).

China's DC/EP stands at the forefront of R&D and implementation of CBDC in leading economies. Up until now, the PBoC has not publicly released documents fully elaborating on DC/EP, we combed the papers and speeches of related PBoC personnel (including Zhou Xiaochuan, Yi Gang, Fan Yifei, Yao Qian, Mu Changchun) to summarize the following features of DC/EP: DC/EP is essentially guaranteed by PBoC, it is a signature issued encryption string the role of which is to partially replace cash M0. It holds no interest, and is issued and circulates following the existing 'Central Bank-Commercial Bank' binary framework, specifically using the 'one currency, two reserves, three centers' framework and it uses the UTXO model. Moreover, it possesses both universality and ubiquity, does not rely on specific transaction mediums and payment channels, and finally it does not assume functions other than the four basic monetary functions. Although the mechanism of DC/EP predates the join report of the CBDC Joint Working Group and BIS it does not violate the three principles. Figure 3 presents the DC/EP's 'Central Bank – Commercial Bank' binary framework, we can see that commercial banks use deposit reserve to exchange DC/EP with PBoC, while customers use bank deposits to exchange DC/EP with commercial banks.

DC/EP is classified as the retail form of CBDC, at the technological level, it requires the use of a permitted blockchain framework to achieve high data output. The primary reasons for choosing the 'Central Bank – Commercial Bank' binary system are as follows: to make better use of the existing commercial banks' hardware and software resources, to stir enthusiasm in commercial banks as the biggest players in China's financial market, to avoid huge increases in workload caused by the public conducting direct business with the central bank while at the same avoiding disintermediation caused by DC/EP and reduce the level of conflict DC/EP has caused with existing financial systems.

After determining the 'Central Bank – Commercial Bank' binary system, another question is how commercial banks should go about managing DC/EP. The public is unable to open an account with the central bank and instead must adjust holdings of DC/EP with commercial banks. One convenient solution is to increase the supervision of DC/EP by making full use of the existing financial systems, that is to increase the function of digital wallets in commercial bank accounts, at the same time having both digital bank accounts and DC/EP wallets with the two being mutually convertible.

The specific implementation model of the 'Central Bank – Commercial Bank' binary system is the 'one currency, two reserves, three centers' framework, which is shown in Figure 4. Of these, 'one currency' refers to the digital RMB issued by PBoC, 'two reserves' refers to PBoC digital currency issuance reserves and commercial bank digital currency reserves. Digital RMB first transfers between the central bank and commercial banks, that is via the issuance and withdrawal of digital RMB, after which it is then transferred to

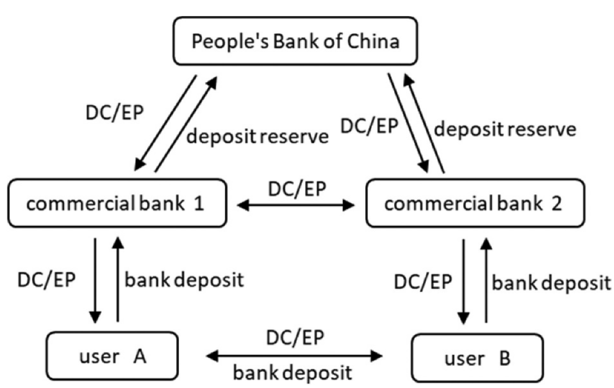

Figure 3. DC/EP's 'Central Bank – Commercial Bank' binary framework.

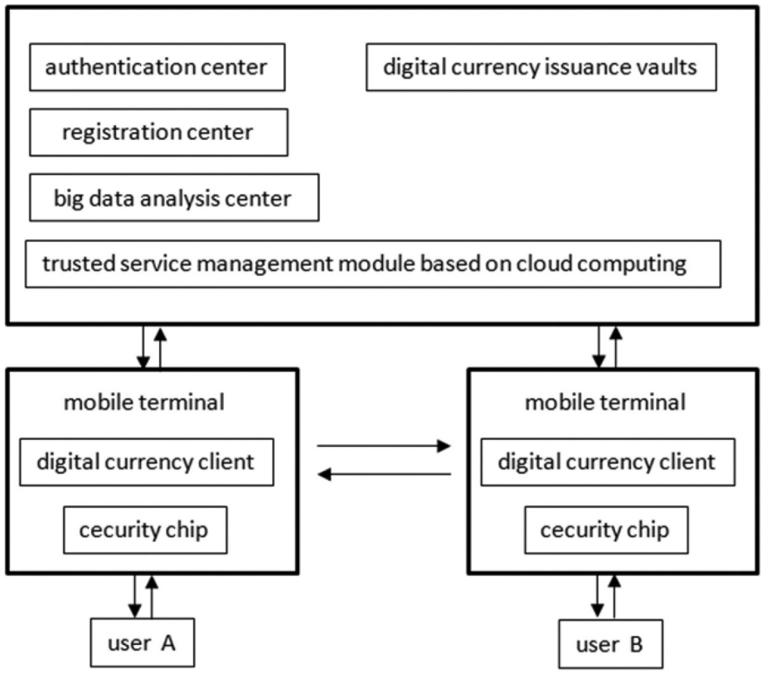

Figure 4. 'One currency, two reserves, three centers' framework.

public hands through the commercial banks. The 'three centers' are the technical safeguards for the issuance and circulation of digital RMB, which comprise the registration center, verification center and big data analysis center. Of these, the registration center is responsible for recording the entire process of issuance, transfer and withdrawal registration; the verification center is responsible for centralized management of the user's identity with the key to ensuring the anonymity of transactions; finally, the big data analysis center uses big data regarding transaction behavior to conduct analysis using monitoring indices in order to monitor illegal use.

In addition, in order for DC/EP to achieve penetrating regulation by the PBoC, it must adopt the UTXO model and adhere to the centralized management model. In UTXO mode, the account balance is the product of aggregate calculation. This type of property is the same as that of cash, allowing it to form a complete chain of funds. The use of the consortium blockchain framework can ensure a degree of flexibility in the digital RMB system. When digital RMB is in circulation abroad, the nodes of domestic commercial banks can be granted to the foreign currency authority, thereby promoting the internationalization of digital RMB.

CBDC has been set up to not only attain its policy objectives, but also to prevent and control potential financial risks. In the midst of the three types of potential risk posed by CBDC, when CBDC has not formed a new price-based monetary policy instrument it cannot bring uncertainty to the existing monetary policy instruments and transmission mechanisms. This is the case for DC/EP at the present stage. When the UTXO model is adopted, it provides a strong regulatory tool for providing access to cryptocurrencies such as Bitcoin through CBDC, at the same time anti-money laundering and counter-terrorism financing (AML/CTF) measures can be embedded in the digital infrastructure such as in CBDC wallets, which largely eliminates this sort of risk. Therefore, CBDC deposits of commercial banks constitute the biggest potential risk, determining how to avoid such risks has become an important part of designing the CBDC mechanism.

In order to prevent and control the systemic risk CBDC poses to bank deposits in terms of substitution, setting up a hierarchical interest rate system is one viable option. In fact, in order to adjust the scale of bank deposits, many central banks have already adopted similar measures toward reserve requirements. DC/EP is positioned partially to replace M0, and in a normally functioning economy M0 has a zero percent interest rate. When a user holds CBDC beyond a certain limit they will incur a certain negative interest rate. The level of the negative interest rate should ensure that even taking the risk premium into account, it is still less attractive than bank deposits and other financial assets. In the event of a financial crisis which causes a sharp rise in public demand for CBDC, the central bank can go one step further and decrease negative interest rates. More complexly, central banks can design third level, fourth level and even more levels of negative interest rates, with each level corresponding to a lower level of negative interest to match different levels of demand for CBDC.

In addition, in the event of a financial crisis, a positive interest rate can be paid to the first tier which is capped at the interest rate on the excess reserves of commercial banks. This would mean that a limited amount of safe assets is provided in times of economic instability, attracting the public to maintain holdings of CBDC at the first tier, which should be calculated according to the requirements of normal circulation, for which the specific figure can be calculated with reference to CBDC holding and transaction data. The central bank can therefore promise a minimum level of first-tier interest rates and guarantee not to charge these negative interest rates, which will offset some of the public CBDC demand, thereby avoiding a run on bank deposits.

The CBDC's tiered interest rate system has significantly improved the effectiveness of CBDC as a monetary police instrument. Over the course of the launch of CBDC in China, there has been a long period of discussion as to whether and how to pay interest. The initial idea of the PBoC was to pay interest in CBDC using adjustment of the CBDC interest rate to bring about the regulation of interest on bank deposits and loans. However, if a floating interest rate were to be given at the early stages of the CBDC launch it would bring new uncertainty to the existing financial system, which is not in line with China's practice of gradual reform. Along with CBDC being clearly defined in China as an alternative to M0 (the official name has also been identified as DC/EP), it has been determined that interest will not be paid in the early stages of the launch. A supplementary program based on this is to design a hierarchical interest system, to implement charging a negative interest rate beyond a certain amount of DC/EP, and in so doing, to break the limit on interest rates to a certain degree, but only as an emergency measure to be used in special circumstances. For the most part, DC/EP will still not pay interest.

On the basis of this, one type of DC/EP operating mechanism which meets China's policy objectives and satisfies the requirements of risk prevention is shown in Figure 5:

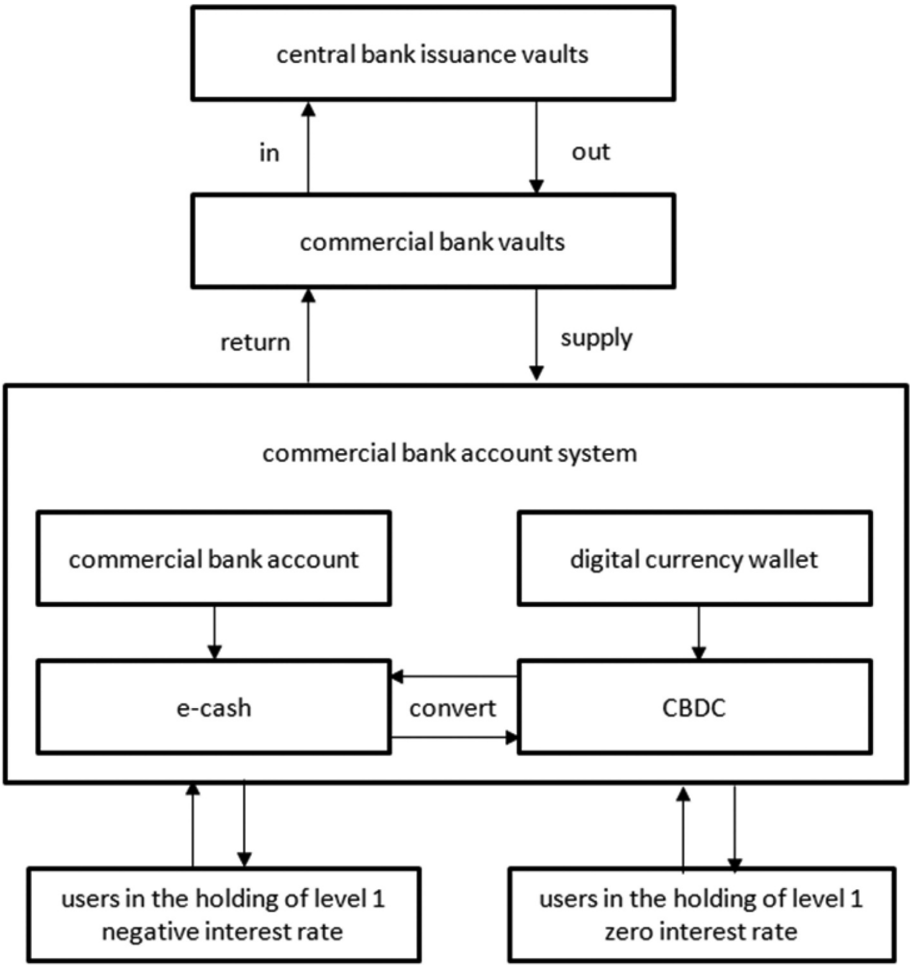

Figure 5. DC/EP graded interest rate operation system.

It should be noted that, on a global scale, CBDC has a tendency to transition from non-payment of interest to payment, when CBDC pays interest it will become a new price-based monetary policy instrument. Non-payment of interest only applies in special circumstances when the interest rate stands at zero, interest significantly expands the space for different policy options and is more conducive to achieving financial and economic market balance.

3. Research on the economic effect of central bank digital currency based on DSGE

CBDC has played a significant role in optimization of traditional legal tender payment methods, it is a significant improvement on existing electronic payment methods in terms of anonymity, CBDC holders only need to provide their real name to PBoC, whereas digital currency holders must provide their real name to PBoC, commercial banks and even third-party payment platforms. At the same time, CBDC is the liability of the central bank, which represents sovereign credit, and is therefore higher than the credit of the commercial banks. Therefore, in theory, the use of CBDC should have positive effect on the economy.

However, one widespread concern is as follows: given the convenience in paying via CBDC, high level of anonymity and higher credit rating, citizens and businesses may convert bank deposits into CBDC in large quantities, leading to the tightening of social liquidity (CBDC is a base currency which does not have the effect of a money multiplier). In addition, in order to reverse this situation, commercial banks must raise deposit rates, which also increases the cost of loans, in turn leading to reductions in the number of loans which further exacerbates the contraction of social credit. This is the so-called 'narrow banking' phenomenon. In particular, if CBDC were to pay positive interest it would increase the probability of this happening. When using CBDC, is necessary to examine the possibility of the occurrence of 'narrow banking'.

At present, only Barrdear and Kumhof (2016) and Yao Qian (2019) have quantitatively studied the economic effects of issuing CBDC on the United States and China using the DSGE model. The results of Barrdear and Kumhof (2016) are of little significance to the issuance of CBDC by PBoC, as it uses the economic parameters from the US. Yao Qian (2019) has drawn on the four-sector DSGE model of Barrdear and Kumhof (2016) and incorporates the interest rate corridor mechanism according to the practicalities of China's economy. Yao Qian's research pointed out that the shock from CBDC will not cause a significant decline in bank deposits, but a small decline after which they will stabilize, whilst also promoting economic growth by 0.01%. However, there is a logical contradiction within Yao Qian's (2019) assumptions: the adjustment cost of bank deposits enters the household utility function as a negative utility, which means that the household's bank deposits, regardless of whether they increase or decrease, bring negative utility to the household. Yao Qian (2019) interpreted this as a service constraint rendered by heavy reliance on savings in bank accounts. This sort of assumption is equivalent to artificially stipulating that households will tend not to adjust the size of their deposits regardless of the existence of CBDC. On the basis of this type of assumption, the resulting expression of the shock from CBDC causing households to trend away from large adjustments of their deposits is relatively easy to understand. However, the cost of adjusting deposits is not in line with the reality of the current bank payment systems. In fact, Yao Qian (2019) also defines deposits as traditional savings deposits, where users cannot use card payment, nor write checks, the only method to change deposited amounts is through withdrawals or queuing at the bank for remittances, which is obviously entirely inconsistent with the reality of the present situation. A more intuitive assumption is that both bank deposits and CBDC can bring positive utility to households, and the two can replace one another, the degree of this form of substitution may change along with the maturation of CBDC-related technology, change in public acceptance of CBDC and change in the degree of demand for anonymous payment.

On the other hand, the role of financial friction is not taken into account in Yao Qian's (2019) model. Bernarke et al. (1999) has noted that there is financial friction in credit market, which may be caused by information asymmetry or other reasons, and that where there is financial friction the initial economic shock is amplified, with a resultantly huge impact on the macro economy as a whole; this is called the 'financial accelerator' mechanism. As a result, the substitution between CBDC and bank deposits as one type of shock may lead to an increase in the cost of bank deposits, thereby reducing the willingness of banks to lend, which in turn leads to a contraction in leverage across the economic system. If financial friction is not taken into account, then the economic consequences caused by this kind of substitution may be underestimated.

In summary, we try to establish a four-sector DSGE model including households, manufacturers, commercial banks and central banks under the framework of the 'financial accelerator' and the correction of household utility functions to study the economic effect of CBDC issued by PBoC on bank deposit substitution.

3.1 Description of the characteristic behaviors of different sectors of CBDC

(1) Family sector

The lifetime utility function of the family sector is as follows:

$$E_0 \sum_{t=0}^{\infty} In(C_t) + \varsigma \ In \ m_t + \varsigma In \ (1 - H_t) \qquad (3-1)$$

C_t is the family's consumption in the t period, H_t is standardized labor time, 1-H_t is leisure time, coefficient η represents the importance of leisure for the family, m_t is the actual balance of currency, this is equal to the ratio of the nominal currency balance M_t to the price level P_t. M_t comprises both CBDC and bank deposits, both in the form of the following CES:

$$\frac{M_t}{P_t} = \left[\alpha D_t^{1-\frac{1}{\theta_t}} + (1-\alpha) B_t^{1-\frac{1}{\theta_t}}\right]^{\frac{\theta_t}{\theta_t - 1}} \qquad (3-2)$$

D_t represents the actual deposit balance, B_t represents the actual balance of CBDC, α represents the proportion of households using bank deposits to pay, (1-α) represents the proportion of payments using CBDC, where it is assumed that the physical currency has been withdrawn from circulation. Under this assumption, the currency mentioned in this article corresponds to broad money (M2) as defined in the hierarchy, θ_t represents the elasticity of substitution between bank deposits and CBDC, assuming that elasticity of substitution obeys the following form of AR (1):

$$\mathrm{In}(\theta_t) \ = \ (1-\rho_\theta) \ In(\theta) \ + \ \rho_\theta \mathrm{In}(\theta_{t-1}) \ + \varepsilon_t{}^{\theta} \qquad (3-3)$$

θ is the steady state value of θ_t and $\varepsilon_t{}^{\theta}$ is the impact of the elasticity of substitution, which may be caused by development in CBDC technology, changes in public acceptance of CBDC, or an increase in the demand for anonymous payment methods.

The budget constraints faced by families are:

$$C_t = W_t H_t - T_t + \quad {}_t + R^D_{t-1} D_{t-1} - D_t + \frac{R^B_{t-1}}{P_t} B_{t-1} - B_t$$
$$C_t \leq \frac{M_t}{P_t} \qquad (3-4)$$

The first budget constraint indicates that the total expenditure of the family in the t period should be equal to the total income in the t period. W_t represents the real wage level during the t period, $T_t$represents tax or transfer payments, Π_t represents the profits of the business sector, assuming that the enterprise is wholly owned by the family. Πtp represents inflation in the t period, $R^D{}_t$ represents the actual interest rate on deposits, $R^B{}_t$ is the nominal interest rate on CBDC, and other symbols retain the same meaning as in the utility function. The second restraint is the Cash in Advance constraint (CIA), which indicates that the household's consumer spending should not be greater than the household's currency balance.

The household maximizes its lifetime utility under the above constraints, the Berman equation for this problem is:

$$\begin{cases} V_t = \max\left\{\ln C_t + \zeta \ln \frac{M_t}{P_t} + \xi \ln(1 - H_t) + \beta \mathbb{E}_t V_{t+1}\right\} \\ s.t. \begin{cases} C_t = W_t H_t - T_t + \quad_t + R^D_{t-1} D_{t-1} - D_t + \frac{R^B_{t-1}}{\ ^P_t} B_{t-1} - B_t \\ C_t \le \frac{M_t}{P_t} \end{cases} \end{cases} \tag{3 − 5}$$

The Lagrangian function is as follows:

$$\begin{aligned} \mathcal{L}_t = {} & \ln C_t + \xi \ln(1 - H_t) + \beta \mathbb{E}_t V_{t+1} \\ & + \lambda_t \left[W_t H_t - T_t + \quad_t + R^D_{t-1} D_{t-1} - D_t + \frac{R^B_{t-1}}{\ ^P_t} B_{t-1} - B_t - C_t \right] + \mu_t (m_t - C_t) \\ & + \eta_t \left\{ \left[\alpha D_t^{1-\frac{1}{\theta_t}} + (1 - \alpha) B_t^{1-\frac{1}{\theta_t}} \right]^{\frac{\theta_t}{\theta_t - 1}} - m_t \right\} \end{aligned} \tag{3 − 6}$$

Here λ, μ and η are Lagrange multipliers of different constraints. The derivative of consumption, labor supply, CBDC balance and bank deposit balance, respectively, can be obtained with the following first-order conditions:

$$\begin{cases} \frac{1}{C_t} = \lambda_t + \eta_t \\ c_t = m_t \\ \frac{\xi}{1-H_t} = \lambda_t W_t \\ \lambda_t = \beta R^B_t E_t \frac{\lambda_t + 1}{\prod^P_{t+1}} + \eta_t (1 - \alpha) \left(\frac{B_t}{m_t}\right)^{-\frac{1}{\theta_t}} \\ \lambda_t = \beta R^D_t E_t \lambda_{t+1} + \eta_t (\alpha) \left(\frac{D_t}{m_t}\right)^{-\frac{1}{\theta_t}} \\ (1 - \alpha)\left(\frac{B_t}{m_t}\right)^{1-\frac{1}{\theta_t}} + \alpha \left(\frac{D_t}{m_t}\right)^{1-\frac{1}{\theta_t}} = 1 \end{cases} \tag{3 − 7}$$

This can be rearranged as:

$$\begin{cases} \lambda_t = \beta R^B_t E_t \frac{\lambda_t + 1}{\prod^P_{t+1}} + \left[(\zeta + 1) \frac{1}{c_t} - \lambda_t \right] (1 - \alpha) \left(\frac{B_t}{c_t}\right)^{-\frac{1}{\theta_t}} \\ \lambda_t = \beta R^D_t E_t \lambda_{t+1} + \left[(\zeta + 1) \frac{1}{c_t} - \lambda_t \right] \alpha \left(\frac{D_t}{c_t}\right)^{-\frac{1}{\theta_t}} \\ (1 - \alpha)\left(\frac{B_t}{c_t}\right)^{-\frac{1}{\theta_t}} + \alpha \left(\frac{D_t}{c_t}\right)^{-\frac{1}{\theta_t}} = 1 \end{cases} \tag{3 − 8}$$

When at a steady state, the inflation rate is equal to 1, and the remaining variables remain the same:

$$\begin{cases} (1-\beta R^B)\lambda = \left[\frac{1}{C}-\lambda\right](1-\alpha)\left(\frac{B}{C}\right)^{-\frac{1}{\theta}} \\ (1-\beta R^D)\lambda = \left[\frac{1}{C}-\lambda\right]\alpha\left(\frac{D}{C}\right)^{-\frac{1}{\theta}} \\ (1-\alpha)\left(\frac{B}{C}\right)^{1-\frac{1}{\theta}} + \alpha\left(\frac{D}{C}\right)^{1-\frac{1}{\theta}} = 1 \end{cases} \quad (3-9)$$

What we get is as follows:

$$\frac{B}{C} = \left[(1-\alpha) + \alpha\left(\frac{\alpha}{1-\alpha}\frac{1-\beta R^B}{1-\beta R^D}\right)^{\theta-1}\right]^{-\frac{\theta}{\theta-1}} \quad (3-10)$$

$$\frac{D}{C} = \left[\alpha + (1-\alpha)\left(\frac{1-\alpha}{\alpha}\frac{1-\beta R^D}{1-\beta R^B}\right)^{\theta-1}\right]^{-\frac{\theta}{\theta-1}} \quad (3-11)$$

The equations (3–10) and (3–11) reflect the demand for both currencies in a steady state. As we can see, along with the rise in interest rate, the demand for bank deposits or CBDC has also increased accordingly, which also reflects the interchangeable relationship between the two.

(2) Manufacturing sector and commercial banks

The same approach is taken as with the standard NK model, firstly dividing manufacturers into intermediate product manufacturers and final product manufacturers. The final product manufacturer is in an environment of full competition, whereas intermediate product manufacturers operate in an environment of monopolistic competition. Final product manufacturers purchase the intermediate products and the use the following techniques to synthesize them into the final product:

$$Y_t = \left(\int_0^1 Y_t(j)\frac{\epsilon_P - 1}{\epsilon_P}\, dj\right)^{\frac{\epsilon_P}{\epsilon_P - 1}} \quad (3-12)$$

Here $Yt_{(j)}$ stands for the jth class intermediate product, ε_p represents the substitutional elasticity between the intermediate product. The demand function for the jth class intermediate product can be obtained from the condition in which the profit of the final product is maximized:

$$Y(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon_P} Yt \quad (3-13)$$

Through completely competitive market zero profit conditions, one can also obtain the price index:

$$P_t = \left(\int_0^1 P_t(j)^{1-\epsilon_P} dj\right)^{\frac{1}{1-\epsilon_P}} \quad (3-14)$$

According to the conditions of the BGG model (1999), intermediate manufacturers can be further divided into two parts: the first part is entrepreneurs who are responsible for the production of non-differential intermediate products; the second part is retailers, who are responsible for the differentiation of non-differential products, and selling these to the final product manufacturers in this way ensuring the characteristics of monopolistic competition.

The production function of entrepreneurs adopts the Cobb Douglas Production Function:

$$Y_t^i = A_t K_t^{\gamma} H_t^{1-\gamma} \quad (3-15)$$

Here Y^i_t represents non-differentiated intermediate goods, K_t represents the invested capital, A_t represents the technical parameters, entrepreneurs at the end of each t period need to use financial institutions (this is limited to commercial banks only) for external financing, the amount of financing is equal to the difference between the price of capital goods and its own net value at t + 1 period, that is to say, the value of assets minus liabilities:

$$B_t^j = Q_t K_{t+1}^j - N_{t+1}^j \quad (3-16)$$

Here Q_t refers to the price of capital goods in the t period, $N^j_{t+1}$is the net value of entrepreneur j in t + 1 period. Capital abides by the following process of change:

$$K_{t+1} = \phi(\frac{I_t}{K_t})k_t + (1-\delta)k_t \quad (3-17)$$

I_t represents the investment expenditure, Φ () represents the adjustment cost of investment, assuming that there is a capital goods sector, taking maximization of profit as its goal, the capital price can be determined as follows:

$$\begin{cases} V_t = \max \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda_{t,t+s}[Q_{t+s}(K_{t+s+1} - K_{t+s}) - I_{t+s}] \\ s.t. K_{t+1} = \Phi\left(\frac{I_t}{K_t}\right)K_t + (1-\delta)K_t \end{cases} \quad (3-18)$$

The Berman equation for this problem is as follows:

$$V_t(K_t) = \max\left\{Q_t(K_{t+1} - K_t) - I_t + \mathbb{E}_t\left[\Lambda_{t,t+1} V_{t+1}(K_{t+1})\right]\right\} \quad (3-19)$$

The Lagrangian function is as follows:

$$\mathcal{L}_t = Q_t(K_{t+1} - K_t) - I_t + \mathbb{E}_t\left[\Lambda_{t,t+1} V_{t+1}\right] + \lambda_t\left[\Phi\left(\frac{I_t}{K_t}\right)K_t + (1-\delta)K_t - K_{t+1}\right] \quad (3-20)$$

The first-order condition is as follows:

$$0 = \frac{\partial \mathcal{L}_t}{\partial K_{t+1}} = Q_t + \mathbb{E}_t\left[\Lambda_{t,t+1} \frac{\partial V_{t+1}}{\partial K_{t+1}}\right] - \lambda_t \quad (3-21)$$

$$\frac{\partial V_{t+1}}{\partial K_{t+1}} = -Q_{t+1} + \lambda_{t+1}\left[\Phi\left(\frac{I_{t+1}}{K_{t+1}}\right) - \Phi'\left(\frac{I_{t+1}}{K_{t+1}}\right)\frac{I_{t+1}}{K_{t+1}} + 1 - \delta\right] \quad (3-22)$$

$$0 = \frac{\partial \mathcal{L}_t}{\partial I_t} = -1 + \lambda_t \Phi'\left(\frac{I_t}{K_t}\right) \quad (3-23)$$

Therefore:

$$Q_t = \left[\Phi\left(\frac{I_t}{K_t}\right)\right]^{-1} \tag{3 − 24}$$

At the end of t period, entrepreneurs need to determine the optimal leverage ratio $Z_{j,t}$ according to their own circumstances. Expected enterprise profits of firms R^K_{t+1} are a random variable, assuming the distribution to beF (R^K_{t+1}), assuming that there is a threshold so that the entire capital value of the entrepreneur is just sufficient to repay their loan, the entrepreneur should choose the optimal loan contract to maximize the value of their own assets:

$$\begin{cases} V_t = \max\left\{ Q_t K_{j,t+1} \int_{\bar{R}^K_{t+1}}^{\infty} R^K_{t+1} dF_R\left(R^K_{t+1}\right) - \left[1 - F_R\left(\bar{R}^K_{t+1}\right)\right] Z_{j,t} B_{j,t+1} \right\} \\ \begin{cases} Q_t K_{j,t+1} = B_{j,t+1} + N_{j,t+1} \\ \bar{R}^K_{t+1} Q_t K_{j,t+1} = Z_{j,t} B_{j,t+1} \\ s.t.\left[1 - F_R\left(\bar{R}^K_{t+1}\right)\right] Z_{j,t} B_{j,t+1} + (1-\mu) Q_t K_{j,t+1} \int_0^{\bar{R}^K_t} R^K_{t+1} dF_R\left(R^K_{t+1}\right) \geq R_t B_{j,t+1} \end{cases} \end{cases} \tag{3 − 25}$$

When R^K_{t+1}>, the value function gives the expected value of entrepreneurs' assets at t + 1. Because when R^K_{t+1}<, all the assets of the enterprise are used to repay the liabilities, the value of the enterprise assets is 0. The first constraint is the identity of the enterprise's assets, liabilities and net value, the second constraint is the expression of the critical value, the third constraint actually means that the profit of the commercial banks should not be less than zero. Specifically, it is assumed that the absorption of private savings is the only source of funds for commercial banks, the right side of the uneven equation is the capital cost of commercial banks. The first item on the left means that when enterprise assets are greater than the critical value, commercial banks can successfully recover the proceeds obtained by the loan. The second item means that when the enterprise faces a shock which has resulted in its income being less than the critical value, the commercial bank needs to pay the costs of status verification, and where there is information asymmetry the commercial bank must cover the costs of conducting a survey of the condition of the enterprise. This simplifies as a set proportion of the loan amount μ. When the enterprise income is less than the critical value, what the commercial bank should recover is the expected value of the enterprises' own assets minus the cost of enterprise status verification. For the sake of convenience, we define:

$$\omega = \frac{R^K_{t+1}}{\mathbb{E}_t R^K_{t+1}} \tag{3 − 26}$$

$$F(\omega) = F_R\left(R^K_{t+1}\right) \tag{3 − 27}$$

$$\bar{\omega}_{j,t+1} = \frac{\bar{R}^K_{t+1}}{\mathbb{E}_t R^K_{t+1}} \tag{3 − 28}$$

The optimization problem can be rewritten as:

$$\begin{cases} V_t = \max\left\{ R_t^K Q_t K_{j,t+1} \int_{\overline{\overline{\omega} j}}^{\infty} \omega dF(\omega) - [1 - F(\overline{\omega} j)] Z_{j,t} B_{j,t+1} \right\} \\ \begin{cases} Q_t K_{j,t+1} = B_{j,t+1} + N_{j,t+1} \\ \overline{\omega} j_{t+1} = R_{t+1}^K Q_t K_{j,t+1} = Z_{j,t} B_{j,t+1} \\ s.t. \left[1 - F\left(\overline{\omega}_{j,t+1}\right)\right] Z_{j,t} B_{j,t+1} + (1-\mu) R_{t+1}^K Q_t K_{j,t+1} \int_0^{\omega j,t+1} \omega dF(\omega) \geq R_t B_{j,t+1} \end{cases} \end{cases} \quad (3-29)$$

The Langrangian function of this problem is:

$$\begin{aligned} L_t = {} & \mathbb{E}_t R_{t+1}^K Q_t K_{j,t+1} \int_{\omega'_{j,t+1}}^{\infty} \omega dF(\omega) - \left[1 - F\left(\omega'_{j,t+1}\right)\right] Z_{j,t} B_{j,t+1} \\ & + \lambda_{1,t}\left(B_{j,t+1} + N_{j,t+1} - Q_t K_{j,t+1}\right) + \lambda_{2,t}\left(\omega'_{j,t+1} \mathbb{E}_t R_{t+1}^K Q_t K_{j,t+1} - Z_{j,t} B_{j,t+1}\right) \\ & + \lambda_{3,t}\left\{ \left[1 - F\left(\omega'_{j,t+1}\right)\right] Z_{j,t} B_{j,t+1} + (1-\mu) \mathbb{E}_t R_{t+1}^K Q_t K_{j,t+1} \int_0^{\omega'_{j,t+1}} \omega dF(\omega) - R_t B_{j,t+1} \right\} \end{aligned} \quad (3-30)$$

From it we can see its first-order condition is:

$$\begin{cases} 0 = \mathbb{E}_t R_{t+1}^K \int_{\bar{\omega}_{j,t+1}}^{\infty} \omega dF(\omega) - \lambda_{1,t} + \lambda_{2,t} \bar{\omega}_{j,t+1} \mathbb{E}_t R_{t+1}^K + \lambda_{3,t} (1-\mu) \mathbb{E}_t R_{t+1}^K \int_0^{\bar{\omega}_{j,t+1}} \omega dF(\omega) \\ 0 = -\left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] Z_{j,t} + \lambda_{1,t} - \lambda_{2,t} Z_{j,t} + \lambda_{3,t}\left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] Z_{j,t} - \lambda_{3,t} R_t \\ 0 = \lambda_{2,t} - \lambda_{3,t} \mu \bar{\omega}_{j,t+1} f\left(\bar{\omega}_{j,t+1}\right) \\ 0 = -\left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] - \lambda_{2,t} + \lambda_{3,t}\left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] \\ \lambda_{3,t}\left\{ \left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] \bar{\omega}_{j,t+1} + (1-\mu) \int_0^{\bar{\omega}_{j,t+1}} \omega dF(\omega) - \chi_{t+1}^{-1}\left(1 - \kappa_{j,t+1}^{-1}\right) \right\} = 0 \\ \left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] \bar{\omega}_{j,t+1} + (1-\mu) \int_0^{\bar{\omega}_{j,t+1}} \omega dF(\omega) \geq \chi_{t+1}^{-1}\left(1 - \kappa_{j,t+1}^{-1}\right) \\ \lambda_{3,t} \geq 0 \\ \geq 0 \end{cases} \quad (3-31)$$

Assuming:

$$h\left(\bar{\omega}_{j,t+1}\right) = \frac{\bar{\omega}_{j,t+1} f\left(\bar{\omega}_{j,t+1}\right)}{1 - F\left(\bar{\omega}_{j,t+1}\right)} \quad (3-32)$$

$$p\left(\bar{\omega}_{j,t+1}\right) = \frac{\int_0^{\bar{\omega}_{j,t+1}} \omega dF(\omega)}{\left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] \bar{\omega}_{j,t+1}} \quad (3-33)$$

$$q\left(\bar{\omega}_j\right) = \frac{\int_{\bar{\omega}_{j,t+1}}^{\infty} \omega dF(\omega)}{\left[1 - F\left(\bar{\omega}_{j,t+1}\right)\right] \bar{\omega}_{j,t+1}} \quad (3-34)$$

After organizing, we can obtain the optimal leverage rate expressed as

$$\kappa_{j,t+1} = 1 + \frac{1 + (1-\mu)p(\bar{\omega}_{j,t+1})}{\left[1 - \mu h(\bar{\omega}_{j,t+1})\right]\left[q(\bar{\omega}_{j,t+1}) - 1\right]} \qquad (3-35)$$

It can be proven that the optimal rate of leverage increases as the difference between R^K_{t+1} and margin on bank deposit interests become larger. As R^K_{t+1} is a random variable, it can be expected that it will tend to have a lower expected level in a period of overall economic downturn. At this moment, if there is a change in the elasticity of substitution between CBDC and bank deposits, it will lead to the transfer of bank savings. In order for commercial banks to prevent erosion of bank deposits, they will have to passively increase the deposit rate, which will lead to further narrowing of the margin of the deposit interest rate, which makes the leverage ratio of the entire economy decrease. This is another major mechanism we have discussed. It should be noted that while such a mechanism may exist, to a large extent it depends on the elasticity of the CBDC and bank deposit substitution. It is currently difficult to draw an accurate conclusion on this point.

(III) Central Bank (PBoC)

With regard to DC/EP in China, the PBoC repeatedly stressed that DC/EP will be compared to M0, that is to say, it acts as an alternative to cash. At the same time, DC/EP does not pay interest. However, each country's CBDC (including DC/EP) only restricts payment of interest in the early launch phase so as to avoid risk as a stopgap measure. With the development of CBDC, interest payments (no matter whether positive or negative rates) are an inevitable trend. In reality, not paying interest is only one special case of paying interest (i.e. interest rates are zero). At the same time, Yao Qian (2019) pointed out that interest-paying CBDC brings the central bank new monetary policy options, taking CBDC interest rate as a monetary policy tool can improve the transmission efficiency of monetary policy. The study by Itai Agur et al. (2019) also points out that interest-paying CBDC is designed to maximize economic benefits in the presence of network externalities. Therefore, we assume that the central bank pay interest on CBDC, and use it as a price-based policy tool, the monetary policy rules are:

$$R^B_t = (1-\rho)\left[\frac{1}{\beta} + \varphi_{\Pi}(\Pi_t - 1)\right]\rho R^B_{t-1} + \varepsilon^B_t \qquad (3-36)$$

Here $\mathcal{E}^B{}_t$ represents the monetary policy shock.

3.2 General equilibrium and quantitative results

(I) General equilibrium

In equilibrium, the total deposit of households should be equal to the total loan of the enterprise:

$$D_t = B \qquad (3-37)$$

In addition, the aggregate demand should be equal to the total output:

$$T_t = C_t + I_t + \mu \int_0^{\varpi} \omega dF(\omega) R_t^k Q_{t-1} K_t \qquad (3-38)$$

Here C_t and I_t are consumer spending and investment spending, respectively, the third item is the bank's status verification costs.

(II) Quantitative results

Firstly, we performed parameter calibration. In light of research by Yao Qian (2019) and Ma Jun and Wang Honglin (2014), we have set the proportion of payment that CBDC takes up as α = 0.5, the coefficient of leisure in utility as ξ = 1, the share of capital in production by enterprises as γ = 0.5, whereas the depreciation rate of capital as δ = 0.03 and the elasticity in demand for intermediate products as $\varepsilon_p = 6$. Since CBDC has not yet been launched, at present there is no more reasonable calibration value for the steady-state value of the substitution elasticity of CBDC and bank deposits. We have assumed that this figure is 1, i.e. that where deposits decrease by 1% there will be a corresponding increase of 1% in CBDC. The remaining parameter calibrations are consistent with the BGG model (1999).

Next, we made the impulse response analysis. Changes in the substitutional elasticity of CBDC will lead to changes in the number of households holding CBDC and bank deposits, so that interest rates on bank deposits passively increase, resulting in the expected profit margins of bank deposits and enterprises decreasing. Corporate leverage will thereby be reduced, which will produce an effect on the economy through financial accelerators. The substitution elasticity impulse response graph is shown in Figure 6:

3.3 Analysis of the impact of economic fluctuations

As shown in Figure 6, the first unit of CBDC substitution elasticity shows a positive effect, which will make CBDC holdings shoot up by approximately 0.002 (B in the graph). However, this growth quickly slows from the second period, and has basically returned to 0 in the fifth period. At the same time bank deposits (shown in Section D) show a decline of 0.02 units in the initial period, but they experience a swift recovery from the second period onwards, essentially recovering to 0 in the final fifth period. This shows that the impact of CBDC substitution on bank deposits is relatively limited; moreover, the timescale is relatively short, there is no steep decline, which is consistent with the conclusions of Yao Qian's (2019) research.

In the short term, the deposit interest rate (Rd in the graph) experiences a significant rise of about 0.023 units, and this rise can also be seen in the long term of about 0.004 units, which may be due to the substitution of bank deposits with CBDC, forcing commercial banks to make 'preventative' increases in deposit interest rates over a longer timescale. In this way interest rates also experience a rise in the long term.

At the same time, the spread (Spread in the graph) also experiences a decline of about 0.0006 units in the short term, and a negative impact in the long term. This signifies a decline in leverage under the financial accelerator framework. CBDC improves the speed and efficiency of central bank currency circulation, increasing the proportion of M0 in the economic system, reducing leverage and also reducing systemic financial risk.

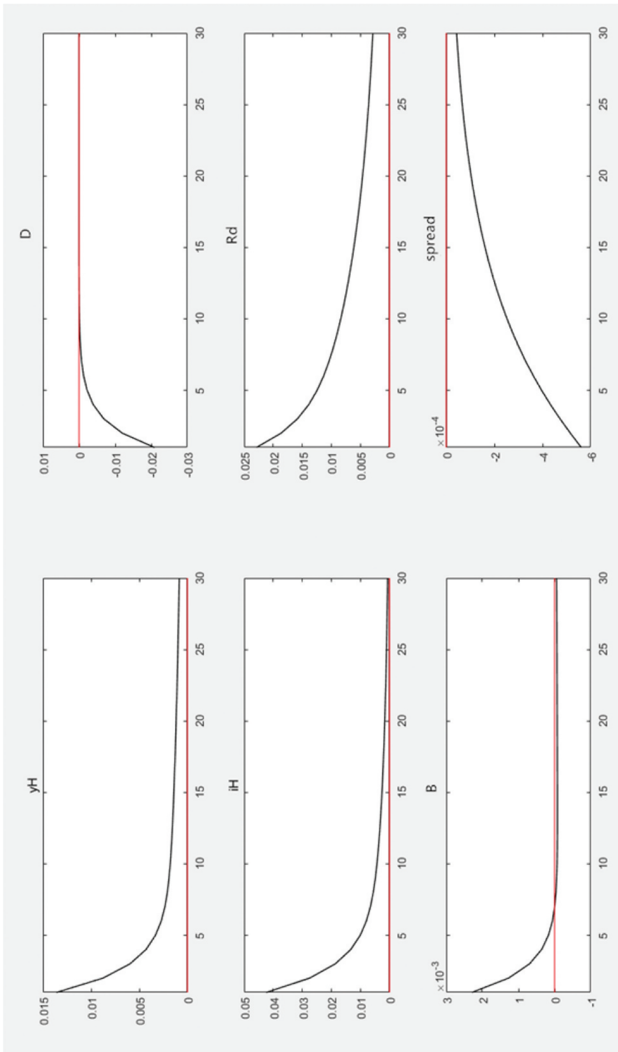

Figure 6. CBDC substitution elasticity impulse response graph.

Finally, CBDC substitution elasticity per positive unit effect would be beneficial to increasing economic production, in that short-term and long-term production would increase by approximately 0.13% and 0.15% units, respectively. This can be attributed to the increased ease of payment, the increased efficiency in macro-control and the reductions in systemic risk introduced by CBDC. Compared to Yao Qian's (2019) study which found that CBDC raised long-term output by 0.01% units, the boost to the economy is more evident, which reflects the fact that the results are more accurate with the inclusion of the financial accelerator effect within the framework.

4. Summary

In the face of competition in global digital currency, China has gradually raised digital currency to the level of national strategy. Promoting CBDC is a systematic and global project. It is supposed to serve policy objectives and prevent potential risks. We examine the mechanism of China's CBDC from both theoretical and practical perspectives in light of the development of digital currencies globally. Moreover, on the basis of correcting shortcomings in the existing literature, we undertake a quantitative analysis of the economic impact of China's issuance of CBDC based on a four-sector DSGE model. The results demonstrate that the impact of CBDC in its use as a substitute for bank deposits is limited, while the unit impact can enhance the economic growth rate by 0.15%, the overall economic effect is positive, at the same time, it reduces the leverage ratio to a certain degree, which is conducive to reducing systemic financial risk. Therefore, we contend that China should accelerate research and development into the central bank's digital currency, launching pilot schemes and promotion of the digital currency; moreover, China should actively participate in the drafting of international regulations for digital currencies, selectively liberalize the jurisdiction of overseas nodes, to jointly establish an integrated digital infrastructure for future generations.

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