Research Paper Series

Exploring the Digital Renminbi: Insights into Chinas CBDC

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Executive Summary

In an era where digital innovations intersect with technology and finance, profound shifts are catalyzing changes in traditional monetary systems. Within this evolving landscape, CBDCs are gaining momentum, and this paper aims to explore the distinctive features and potential applications of China's Digital Renminbi, beginning with a comprehensive overview of CBDC fundamentals and the evolution of the e-CNY development. Following this foundational overview, the paper will report an assessment of financial inclusion across China, contextualizing the role and impact of CBDCs. The core part of the paper will focus on the design of the architectural model, delving into its distribution model, the key principles underlying the Digital Wallets and the technological framework that supports the Chinese CBDC. The final section introduces the cross-border payment paradigma with mBRIDGE, a project at first and then a real exchange platform. The international involvement of the participants acted as a sounding board to raise awareness of the collaboration between central banks, commercial banks and corporate institutions. Considerations will be given regarding a future made of interconnections, where efficiency and privacy play a key role.

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This document was prepared in collaboration with Pietro Maria Cepparulo and Nicola Mazzoni, who at the time were working for Iason Consulting.

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The financial sector has seen a period of important changes over the last few years due to improvements in technological innovation and changes in user preferences. In this scenario, considering the decline in cash usage and the increase in the development of digital payment platforms, Central Bank Digital Currencies have become a focal point in the field of central bank analysis for modernizing monetary systems without compromising central bank authority. In this sense, China's Digital Renminbi has led the world's major economies in pushing forward the development of the CBDC project with its advancements in the development of its CBDC, the Digital Renminbi. The purpose of this paper is to outline the progress in the Digital Renminbi development, describing its peculiarities by examining the architecture of e-CNY, its possible benefits, and its broader implications in the global landscape of CBDC development. More precisely, the analysis will cover the characteristics that identify the design of the Digital Renminbi, explaining the peculiarities of its two-tier distribution model, the e-CNY digital wallet typologies, and the technologies behind it. The conclusions will underline the cross-border implications of e-CNY and further outline the ongoing development status of the mBridge project. Considerations through this discussion will lead to studying the implications of a future made up of interconnections, where efficiency and privacy intervene as two key players.

1. Introduction to CBDC

The technological innovations of the last decade have brought disruptive changes in the financial sector. In particular, we have witnessed a shift in user behavior with a decline in cash usage in favor of new ways of payments and the rise of new platforms that offer diversified services related to financial services. In this context, Central Banks have begun to closely monitor these new paradigms with a certain concern about the possibility that central bank money (the money that is issued by a Central Bank and guaranteed by the public authority, in contrast with the commercial money that is the money detained at banks that are guaranteed by the financial stability of a particular institute) will lose its importance as the center of the exchange system. These conditions are the ones that have fostered the increasing interest in the Central Bank Digital Currencies (CBDC). CBDCs are nothing less than fiat money issued at par with the physical money issued by the Central Bank that will serve as a payment method, being so legal tender money, and a store of value such as its paper counterpart. CBDC could also be distinguished by the plethora of users that they are designed for: wholesale CBDCs are distributed among financial institutions and used for interbank transactions, while retail CBDCs are intended for the general public, retail users, and businesses. This chapter aims to clarify the main features that a Central Bank could take into consideration while planning to issue a CBDC and also inquiring the potential benefits and implications for the financial sector and the political economy.

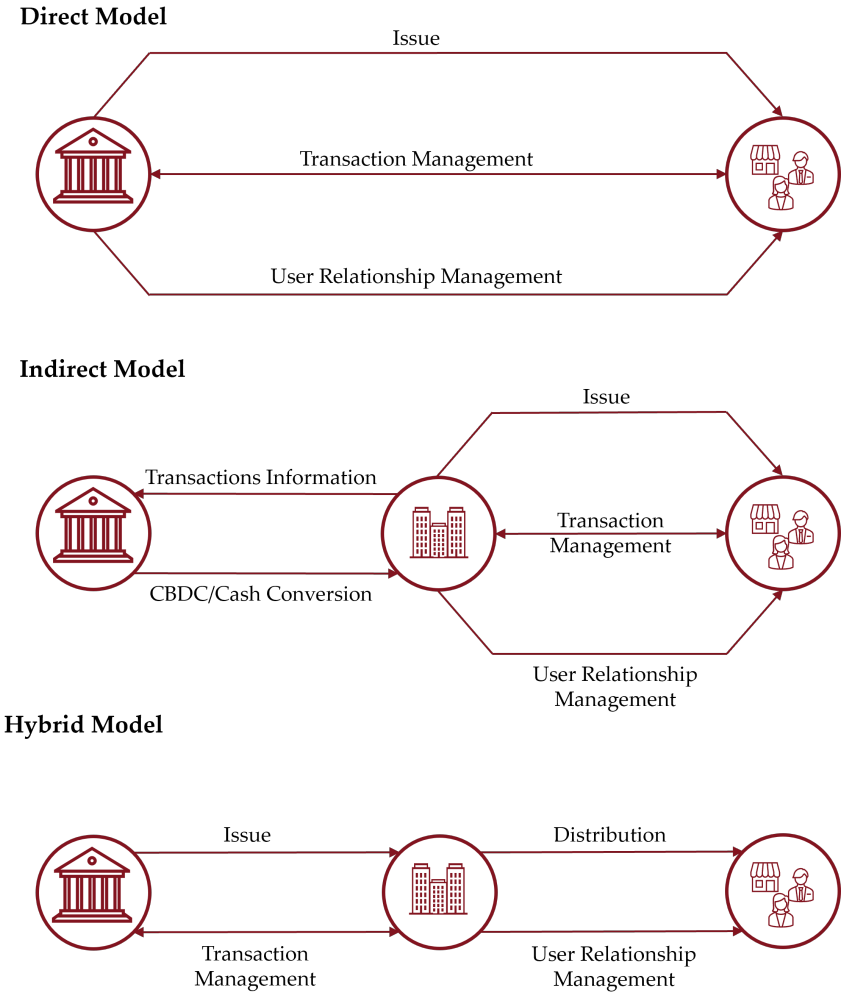

FIGURE 1: Distribution Models

1.1 The CBDC Environment

1.1.1 Distribution Models

In the development of the CDBC system, one of the most important decisions to be taken into consideration is the role that actors of the economic system have to fulfill in terms of issuing and distributing the CBDC. The design of the Distribution Model involves the duties that have to be covered regarding the management of:

- **CBDC Issuing;**
- **Transaction Management;**
- **Users Relationship.**

Three models are usually considered to address a CBDC system, and these can be distinguished as follows:

- **Direct Model;**
- **Indirect Model;**
- **Hybrid Model.**

In the Direct Model, the Central Bank plays a pivotal role within the system considering that this configuration requires that all the activities regarding the issue, the transaction management, and the

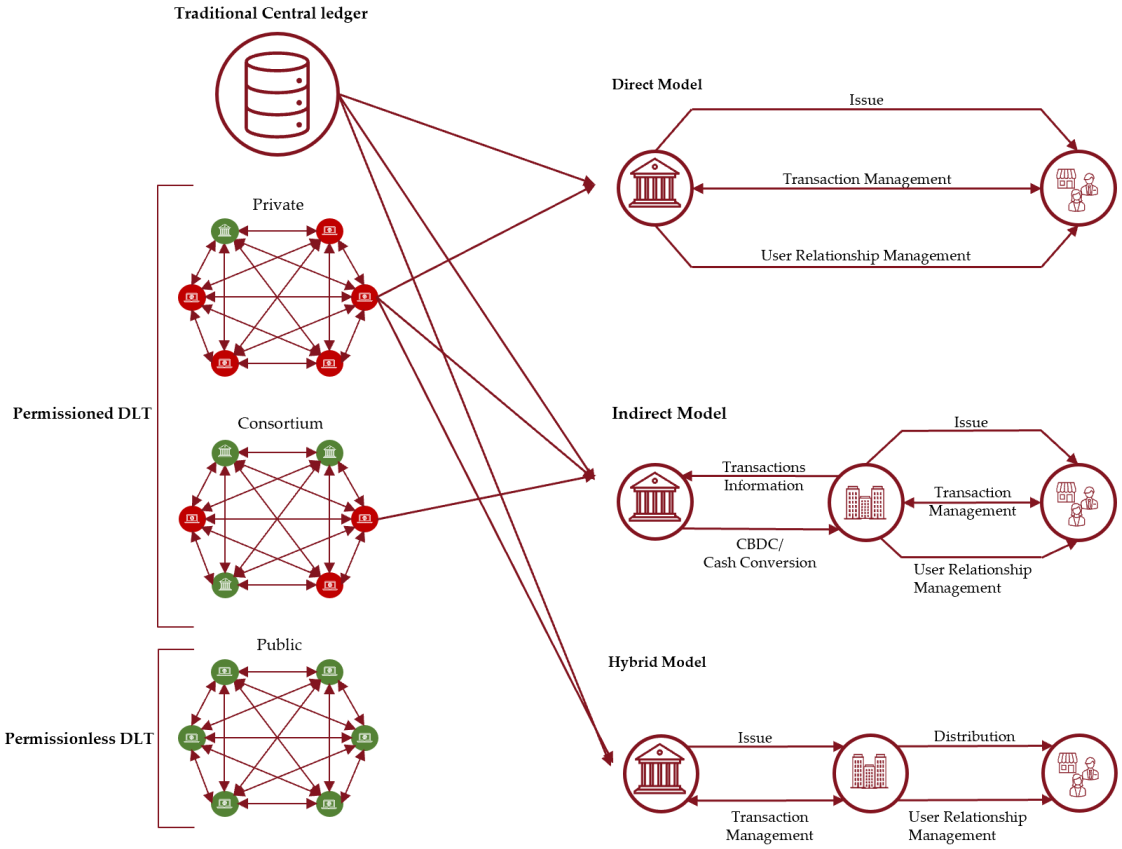

FIGURE 2: Architectural Models

users'relationship must be performed by the Central Bank. The Direct Model requires the Central Bank to act as a Bank recording in its ledgers the issued CBDC as its liabilities while performing the settlement of the transactions and the management of relationships as the onboarding activities and the monitoring of the accounts.
The Indirect Model shifts the focal point of the distribution system to the Private Sector (e.g. Commercial Banks) which holds the role of the main actor in the full cycle of the CBDC being in charge of issuing it and managing the transaction among users. In this case, the Central Bank still guarantees the conversions between CBDC and cash while also monitoring the gross amount of deposits in the intermediaries' accounts.
The Hybrid Model requires a mutual division of roles between the Central Bank and the Private Sector. In this configuration, the Central Bank acts as the CDBC issuer while also managing the settlement of the transactions. These features imply that the CBDC is recorded as a liability of the Central Bank and also thanks to transactions management activities the Central Bank will always be aware of the total amount of the CBDC stock within the system. On the other hand, the Private Sector acts as the CBDC's distributor to the end-users and the curator of relative relationship management.

1.1.2 Architectural Models

A second step in the development of a CBDC environment regards the technological framework that the system will rely on. Two options are usually identified: rely on the entire system on a traditional central-based ledger or developing an Environment that purely relies on DLTs, "a database distributed in identical copies among the nodes that compose the environments. The peculiarity of DLTs is that the ledgers among the nodes chain are simultaneously updated through a consensus mechanism. The node's network is in charge of the maintenance of the ledgers implying the continuous update of the information stored in the registries."[22]Considering the possible

Distribution Models explained a Permissioned Private DLT, a Digital Ledger where the transaction validator role is in the hand of the Central Authority (typically the Network owner), could be the best feasible for the Direct and the Hybrid models where the transaction management is directly in charge of the Central Bank, while for the Indirect Model it could also rely on Permissioned Consortium DLT where the validators are chosen between a set of trusted validators. Considering the role of the CBDC, the application of a pure Public Permissionless DLT, where every actor of the network works as a validator through the application of a consensus mechanism, seems to have more than one technical issue. In particular, it could highlight the scalability of transactions and the reduction in speed generated while managing simultaneous high transaction volumes. The configuration that could be reached by implementing a system that relies on a Permissioned Private DLT is much more similar to the scenario where a Central Traditional Ledger is applied.

1.1.3 Accessibility

A third important feature in designing a CBDC Environment regards the way in which there are accessible to the users. The options swing between:

- **Account-Based Model;**
- **Token-Based Model.**

The Account-Base Model is essentially the typical commercial Bank's model that links the claims deposited into an account to a specific user's identity. In this case, the model relies on the principle "I am so I own"[3]. The Token-Based Model, similar to what happens in the Blockchain, relies on cryptography authentication methods and requires the knowledge of a private key in order to access to CBDC account. It is clear that this last configuration permits a higher degree of privacy level for the users as the information stored in the ledgers regards only the transaction flows while the user's identity is registered as an alphanumeric code. On the other hand, the traditional Account-Based Model permits, nevertheless a lower degree of privacy level, an easy-to-perform KYC and AML controls.

1.2 Potential Benefits

The rise of CBDCs could mean a significant shift in how we approach economics, offering a range of potential benefits across different aspects of the financial system. In particular, there are specific aspects where CBDCs could bring substantial advantages:

- **Financial Inclusion;**
- **Financial Innovation;**
- **Cross-Border Transactions;**
- **Transaction Transparency.**

The development of a CBDC could significantly boost financial inclusion in those systems where the population faces several issues with being part of the traditional bank system. In developing countries, a significant portion of the population could not benefit from typical services related to traditional bank activity, such as payment services and deposit accounts, due to various reasons, including the costs of maintaining a bank account and difficulties in providing necessary documentation. A CBDC environment through the development of specific Digital Wallets could ease the possibility of accessing a vault that stores digital money and a way to perform digital payments without the need for a bank account. In this way, the financial system could reach that part of the population that is historically "unbanked" (In 2021, nearly 1.4 billion adults lacked access to a bank account) guaranteeing the possibility to access basic financial services. Following the concept of financial inclusion and considering that, in 2023, nearly 6.9 billion people worldwide have smartphones, a Central Bank (considering a direct or a hybrid distribution model) could develop its own mobile application, offering basic services such as money deposits and payment services, thus helping the unbanked population bypass the traditional banking system. The People's Bank of

China (PBoC) has already developed its own application for the Digital Renminbi, and the European Central Bank has already defined that in case of the development of the Digital Euro will be developed a "ECB App" that will offer the core services defined under the Digital Euro Scheme[23]. The development of a Central Bank links also with the boosting of financial innovation that CBDCs could bring to the financial system. The introduction of a digital infrastructure that supports the CBDC could operate as the catalyst effect that will foster financial innovation within payment solutions and money management. Considering in particular the indirect and the hybrid models relying on the Private Sector for managing several activities related to the CBDC environment (e.g. Distribution, KYC, AML) could encourage the development of several innovative solutions to meet the market needs with beneficial effects also on the competition of the market. The financial innovation related to the introduction of CBDC could also foster the improvement of the current Cross-border transactions market. Except for the inside European Union transactions, domestic payment systems across the world are not interoperable with each other and often require the actions of several intermediaries in order to assess and close the transactions, thus the introduction of CBDC could cut off most of these actors linking the users directly and also having a rebound effect on reducing the transaction costs. Additionally, having an entirely digitalized environment could support the financial authorities and the private sector in mitigating the risks related to tax evasion and money laundering.

1.3 Implications for the Bank System and Political Economy

Since the beginning of the theorizing on the issue of CBDC, the literature has pointed out several potential implications for both the Bank Sector and for the Political Economy. The main issue regarding the banking system is related to the potential increase in liquidity risks, disintermediation, and possible bank runs that could be addressed by the introduction of a CBDC. In particular, the introduction of a digital central bank money, guaranteed by a Central Bank, that could be stored in digital wallets which, even in those models where the private sector could open and manage digital wallets of the users, are segregated from the bank's capital could encourage a shift into users preferences moving their deposits to a less risky alternative, the digital wallets. It is clear that a reduction of bank deposits in favor of CBDC's Digital Wallets could severely affect the bank funding activity with rebound effects on the related lending activity. In fact, a reduction in deposit amounts could force banks to fund their activities through more expensive funding sources. The use of expensive market instruments, such as debt issues, to raise funds could tighten the credit offer with negative effects on the whole economic system. On the other hand, relying on Central Bank Loans "they would have to give the Central Bank enough collateral, which would drive up the price of secure assets and change their market rates."[25]Other than that, the possibility of moving money digitally from deposits to digital wallets without any specific limitation could boost the risk of faster and more contagious bank runs. In the definition of the main Features of a CBDC, two main variables could be manipulated to mitigate the risks that the banking system could face:

- **CBDC Limit Detention;**
- **CBDC Remuneration.**

The limit detention could regard both the limitation with an upper limit to CBDC detention and the maximum amount that could be withdrawn. The detention limits could also distinguish between households and firms, for example, the actual possible design for the Digital Euro states that there will be differences in the detention limits between private citizens (still not disclosed the upper limit) and business users that "will be set a zero holding limit, which implies their impossibility of detaining Digital Euro amounts stored in their account"[23]. The effect that a detention limit could have on the European banking system has been studied by M.Azzone and E.Barucci[1] which under the assumption of a capped adoption scenario (substitution of 647 billion euros of deposits with a personal detention limit of 3.000 Digital Euros) showed that the introduction of a CBDC should negatively affect the bank's deposits with a reduction of less than 10% of the total deposits amount. Also, a scenario with a no remunerated CDBC will bring a lower loss for the mass of the deposits with a non-significant probability for bunk runs. The remuneration of the CBDC plays, as well as the detention limit, a key role in the possible decisions of the users in terms of preference between

CBDC or bank deposits. As stated before a non-remunerated CBDC could lower the negative effects on the banking systems. Despite that PBoC has designed the e-CNY in this way, the ECB has declared that the Digital Euro will not bear any interest, and several other projects have moved in this way (e.g. Sand Dollar, E-Naira) an interest-bearing CBDC is still possible. However, to avoid the users'shift from bank deposits to CBDC, several constraints on the possible remuneration that the CBDC should grant need to be considered. U.Bindesil[4] has proposed a two-tier model that will help to encourage the detention of a certain amount of CBDC for payment purposes, but not as a direct substitute for bank deposits, and on the other hand will discourage its detention for investment purposes. The idea is that under a certain amount of money, the CBDC will grant the maximum rate between 0 and the Deposit Facility Rate -1%, which will ensure a minimum remuneration for the CBDC detained for payment purposes that will still be less than the bank deposits one. Exceeded the defined amount of the interest grant for the CBDC will shift to the minimum between 0 and the Deposit Facility Rate -1%, which will ensure a "punitive" treatment for those who detain too much CBDC.

- If CBDC Detained < detention threshold : $i_{CBDC} = max(0, R_{DF} - 1\%)$;
- If CBDC Detained > detention threshold : $i_{CBDC} = min(0, R_{DF} - 1\%)$.

With this configuration, a regime with high rates will always guarantee remuneration for the CBDC detentions that don't exceed the threshold that won't surpass the one paid by the bank's deposits. Under a regime of low rates, the competitiveness of bank deposits will be guaranteed by the absence of remuneration for the CBDC amounts under the detention threshold. Moving to the implications that issuing a CBDC could have on the Political Economy plan of a Central Bank, we should distinguish between the effects of the retail CBDC and the wholesale CBDC. The introduction of a CBDC into the economic system could lead to a shift into the detention preferences of households and businesses that could prefer to fund digital wallets with CBDCs instead of detaining cash in their pockets or bank deposits. The implications of the possible shift in preferences could lead to severe causes affecting money velocity, bank disintermediation (as stated before), and the number of reserves detained in the Central Bank. The digital nature of CBDC could easily affect the monetary exchanges in the economic system as digital payments do not have the same physical barriers that characterize cash exchanges and also the settlement and the accounting of monetary units on the digital wallet will occur with a lower lag than the necessary time to deposit cash into bank accounts. Considering the Velocity of Money as:

$$V_t = T_n / M. \tag{1}$$

Is easy to figure that the increase of exchanges T_n driven by the digital nature of the CBDC could lead to an increase of the Velocity of Money, this could break the relationship between money and inflation affecting the monetary targeting of the Central Bank. In fact, looking at the relation between the Monetary Mass and the PIL of a country defined by the equation:

$$M_t x V_t = P_t x Q_t; \tag{2}$$

$$P_t = (M_t x V_t) / Q_t, \tag{3}$$

where:

- M_t: Money Mass[1];
- V_t: Velocity of Money;
- P_t: Average Price Level;
- Q_t: Production.

We can state that the average price level increases with increasing in the total money volume ($M_t x V_t$). So considering the Money Mass as a variable under the control of the Central Bank, is it clear that the possible quick growth of the transactions that a digital, unconstrained, central bank currency could carry should bring a steepen in the inflation levels. Other than that, the introduction

[1]The total average nominal amount of money in circulation in the economy.

of a retail CBDC could modify the cost configuration related to cash management, lowering the costs of banknote printing, carry and distribution but opening up to new costs arising from the CBDC implicit structure. "Depending on these changes in seigniorage income, central banks might increase or decrease their reliance on government funding, impacting their independence in shaping monetary policy"[23]. As already stated, the introduction of a CBDC could drive to a decrease in bank deposits, among everything this could also bring to a reduction of the reserves that the commercial banks held in the Central Bank with effects on the Open Market Operations. On the other hand, the introduction of a wholesale CBDC won't affect the monetary policy effectiveness but will bring a shift in the market structure redesigning the composition of the Central Bank liabilities through a decrease of commercial bank's reserves and a contextual increase of the wholesale CBDC. The considerations reported make clear that Central Banks should take several precautions before issuing a CBDC, in particular fixing threshold and limitation on both detention amounts and the transactions could hurt the demand for the CBDC but on the other hand could ensure the stability of the whole financial system. In the same way, careful policies regarding the remuneration, such as a two-tier rate configuration or a non-interest-bearing CBDC, of the CBDCs could help avoid an increase of both disintermediation and liquidity risk.

1.4 History and Development of the Digital Renminbi Project

Concerning the practical development and testing of its capabilities, significant progress on the e-CNY project was confirmed in November 2019 by Fan Yifei, the former deputy governor of the People's Bank of China (PBOC). He stated that major tasks such as high-level design, standard formulation, and functional research and testing of the legal digital currency had been completed. Pilot tests took place in various cities across China in the following years. The selection of pilot locations for the e-CNY R&D project considered factors such as major national development and regional coordinated development strategies, in addition to city-specific industrial and economic characteristics considerations. The goal was to verify the reliability of theories, the stability of systems, the usability of functions, the convenience of processes, the applicability of scenarios, and the controllability of risks.

In April 2020, the cities belonging to the "China's Silicon Valley": Shenzhen, Suzhou, Xiong'an, and Chengdu were announced as the first batch of pilot cities to enter the program. In the following months, the PBOC entered negotiations with internet companies, including ride-hailing major Didi Chuxing, to test the use of the digital currency. This effort positioned the nation as a pioneer in experimenting with the e-CNY. Didi Chuxing stated that it had inked a strategic partnership deal with the Digital Currency Research Institute of the People's Bank of China to explore the use of digital Renminbi in the smart transportation sector. Additionally, the PBOC contacted the major food delivery company Meituan Dianping, in Beijing, to discuss the pilot program and the related promotion plans across the entire platform. Other companies, such as video broadcasting websites Bilibili, also announced his active participation and cooperation efforts. To further stimulate the usage of e-CNY, in October, the PBOC distributed digital "red envelopes" containing a total of 10 million e-CNY to 50.000 citizens in Shenzhen. The e-CNY could be spent in Shenzhen's Luohu District at merchants that had completed the digital RMB compatibility transformation. Citizens gained access to these red envelopes through a lottery system. The 3,389 participating merchants, including restaurants, supermarkets, gas stations, metro stations, department stores, and other businesses that had completed the digital RMB compatibility transformation, allowed recipients to spend the gifted amount between the 12th and 18th of the month. This incentive method will also be implemented on future multiple occasions and in various cities as a means to encourage the usage and familiarity with the Digital RMB.

The pilot test advanced in its extension further in November with the inclusion of Shanghai, Hainan, Changsha, Xi'an, Qingdao, and Dalian as pilot areas, representing the second batch of digital RMB pilot testing cities. For some of the mentioned cities, the e-CNY project was integrated and developed as part of the cities' respective five-year development plans. These plans are comprehensive frameworks crafted by local governments to delineate economic, social, and environmental goals, along with initiatives to be accomplished over a five-year period, in alignment with national priorities. For instance, Shanghai enthusiastically embraced participation in the program, aligning with its involvement in the "14th Five-Year Plan for Comprehensively Promoting Urban Digital

Transformation in Shanghai" Fintech innovation project. The primary objectives of this initiative included the promotion of new financial technologies, enhancement of financial industry efficiency through digitalization, improvement of institutional service levels, and enhancement of convenience and inclusiveness in financial services. Similarly, the "14th Five-Year Plan for the Development of Hainan Province's Financial Industry" advocated for the launch of e-RMB pilot projects across the island, aiming to explore application scenarios of e-RMB tailored to the characteristics of the "Hainan Free Trade Port" initiative. The comprehensive objective of the latter is to transform Hainan into a global hub for free trade, thereby facilitating international exchanges more effectively. The Digital RMB could significantly contribute to achieving this objective by enhancing the efficiency and transparency of cross-border payments, reducing associated costs, ensuring traceability and supervision of cross-border capital transactions, and promoting the development of new offshore international trade and related business activities.

A key milestone regarding the promotion of the e-CNY among private companies, and more specifically, e-platforms, occurred when the second-biggest online retailer giant Jingdong (JD.com) became the first of its category to accept payment in digital Yuan. On December 11, 2020, JD.com distributed 100.000 digital cash vouchers, totaling 20 million yuan, to residents of Suzhou for use on specific items available in their store.

In February 2021, to implement the action plan for the Winter Olympics of science and technology and strengthen the payment service environment for the Beijing Winter Olympics, the People's Government of Dongcheng District, in Beijing, hosted the "Digital Wangfujing Ice and Snow Shopping Festival" digital RMB pilot activity. This festival was designed to integrate digital RMB usage across various consumption scenarios related to the Winter Olympics. As part of this initiative, 50,000 digital RMB red envelopes were distributed to winners through appointment registration and lottery distribution, with each red envelope containing 200 Yuan. Winners were able to spend this digital RMB at designated merchants in the shopping street of Wangfujing and within the festival activity area at Jingdong Mall. This pilot activity showcased the practical applications of digital RMB in a festive and consumer-oriented setting, highlighting its potential role in enhancing payment services during major events.

Another significant advancement in the progress of pilot testing occurred in March 2021 with the promotion of the digital RMB currency wallets on the app of the six major state-owned banks: The Industrial and Commercial Bank of China, Agricultural Bank of China, Bank of China, Bank of Communications, China Construction Bank, and Postal Savings Bank of China. Customers interested in participating in the promoted pilot test could apply either by visiting a branch of the participating banks or by enrolling in a whitelist, scanning the provided QR code, registering on the e-CNY app, and opening the sub-wallet. Initially, there would be a daily cumulative payment limit of 1.000 Yuan, with the option to apply for an upgrade in the future.

"As of June 30, 2021, e-CNY was applied in over 1.32 million scenarios, covering utility payment, catering service, transportation, shopping, and government services. More than 20.87 million personal wallets and over 3.51 million corporate wallets had been opened, with transaction volume totaling 70.75 million and transaction value approximating RMB34.5 billion"[31]. Meanwhile, as of October of the same year, "approximately 140 million Chinese residents had opened a digital Yuan account through either payment or banking apps, with accumulated transactions reaching 62 billion Yuan since its launch. Mu Changchun, the head of the Digital Currency Research Institute, said in November"[13].

Starting from January 2022, the digital RMB pilot version app became publicly available on app stores such as Apple, Huawei, Xiaomi, Vivo, and Oppo for residents of the cities where the pilot program was being conducted. Following its release, the app quickly ranked among the most downloaded apps in the subsequent days, reflecting significant interest and adoption among users in these areas.

During the Beijing Winter Olympics, the digital Renminbi garnered international attention and interest. In all the areas and related provinces of Beijing and Zhangjiakou where the games took place, consumers could use the digital Yuan not only at the Olympic venues but also for a variety of services, including transportation, catering, accommodation, shopping, sightseeing, healthcare, telecommunications, and entertainment. People from around the world could all use it via smartphone apps, or with wearable devices such as wristbands , or even ski gloves . Additionally, special

ATMs were strategically installed for this purpose. These ATMs were equipped todirectly convert up to 18 types of foreign currencies (e.g.: Euro, US Dollar, Swiss Franc, Norwegian Krone) into Digital RMB. Users could insert banknotes into the machine, confirm the amount and exchange rate, and then receive a physical card from the ATM, which served as a physical digital RMB wallet. In terms of privacy protection, the PBOC governor, Yi Gang stated that data collection concerning the CBDC would adhere to the principle of "anonymous for small-value and traceable for large-value transactions."[16], assuring that the volume of data collected for the CBDC would be lower than that of existing e-payment instruments. In terms of figures, as estimated by a senior official from the PBOC, the e-CNY facilitated payments of 2 million Yuan or more per day during the Winter Olympics.

After the Olympics, the PBOC widened the scope of the digital Yuan pilot program by incorporating 11 additional cities. These new pilot areas encompassed Tianjin, Chongqing, Guangzhou in Guangdong Province, Fuzhou, and Xiamen in Fujian Province and, additionally, six cities dedicated to host the Winter Games - Hangzhou, Ningbo, Wenzhou, Huzhou, Shaoxing, and Jinhua - were included, marking them as the third batch of pilot cities.

In December, the fourth and final batch of pilot cities was introduced, encompassing the city of Jinan, Nanning, Fangchenggang, Kunming, and the Xishuangbanna Autonomous Prefecture. During the same month, Alipay integrated the digital Yuan into its services ecosystem, including platforms like Taobao for online shopping, Ele.me for food delivery, Freshippo for grocery retail, and the Shanghai Public Transport system. On the e-CNY app, users were enabled to set both single payment limits and daily cumulative payment limits for transactions conducted via Alipay utilizing the digital Yuan.

In May 2023, a remarkable development occurred in Changshu: public sector workers in the city began receiving their entire wages exclusively in digital Yuan. The policy affected government employees and staff at state-owned companies and public institutions, such as schools, hospitals, libraries, research institutes, and media organizations within the city. According to the Chinese state media, this rollout represents the largest implementation of the digital Yuan recorded thus far. Later, in July, the Bank of China, China Telecom, and China Unicom jointly collaborated to launch the SIM card hard wallet product within the digital yuan app. Available only to Android mobile phone users, the SIM card hard wallet integrates a super SIM card with the e-CNY soft wallet. Users only need to install a super SIM card issued by the operator on their mobile phones, log in to the e-CNY APP, open a SIM card hard wallet, and use the Near Field Communicatio (NFC) function of the mobile phone to complete the e-CNY payments.

The Digital Renminbi has made significant progress compared to the digital euro. The PBOC has expanded its pilot programs rapidly, covering various cities and scenarios, including public sector payrolls and large-scale events like the Beijing Winter Olympics. Technologically, the e-CNY has introduced features such as the SIM card hard wallet, enabling offline transactions and demonstrating a robust infrastructure supported by major tech and financial institutions. Collaboration with the private sector, such as integrating the digital Yuan with Alipay and Taobao, highlights China's seamless blend of public and private efforts to promote the currency. In addition, China's proactive user adoption initiatives, including distributing digital cash vouchers and usage campaigns, further demonstrate its advanced position in CBDC deployment. The Eurosystem's back-end prototype, named NXT, utilized an unspent transaction output (UTXO) data model, a common framework for digital currency transactions. This system demonstrated its capability to support various types of transactions while safeguarding users' privacy by not disclosing their payment patterns or account balances to the Eurosystem. Concurrently, market participants successfully implemented and tested all five payment scenarios, exploring innovative approaches such as self-custody wallets, which could potentially enhance privacy pending future legislative developments. The exercise also served to technically assess the interface between the front-end and back-end layers, with results indicating smooth interaction. However, it is important to note that since all prototypes were developed entirely from scratch, the exercise did not account for the potential effort required to adapt existing payment service provider (PSP) systems. Looking ahead, the future steps for the Digital Euro involve finalizing the legal framework, ensuring financial stability measures, determining the appropriate technology for the settlement system, and addressing security and integration concerns. On June 28, 2023, the European Commission presented a regulatory proposal to ensure the legal tender status

of the digital euro. The acceptance of this proposal is crucial for its widespread acceptance and distribution across the Union, aiming to bring the appreciated features of cash into the digital sphere and ensuring that the digital euro adds value for people. The investigation phase clarified several issues, including measures to ensure the financial stability of the Eurosystem and to avoid bank disintermediation effects. There will be a limit on digital euro holdings for private users, which will be disclosed just before its issuance, and a zero holdings limit for business users to prevent its use as an investment instrument. Additionally, a remuneration system for digital euro holdings will not be implemented to discourage its use as an investment tool. The ECB has not yet disclosed the underlying technology for the back-end settlement system of the digital euro. The options being considered include the implementation of Distributed Ledger Technology (DLT), reliance on traditional technologies, or a combination of both. The ECB will prioritize the security level of the technology and the feasibility of integrating it with existing end-user services.
In summary, it can objectively be stated that the e-CNY is ahead in practical deployment, technological integration, and user adoption compared to the digital euro, which remains in the early stages of development and has yet to be introduced to the EU citizens.

2. Financial Inclusion

As discussed in the previous chapter, the development of a Central Bank Digital Currency (CBDC) could be pivotal in promoting financial inclusion in countries where traditional banking methods are not readily accessible. The barriers vary, encompassing geographical challenges, income disparities, gender gaps, and educational levels, among others. Such difficulties become more pronounced in a rapidly growing nation like China, which needs to maintain the pace of development while simultaneously improving the quality of life. According to the World Bank[32], financial inclusion refers to "The uptake and usage of a range of appropriate financial products and services by individuals and micro and small enterprises (MSEs), provided in a manner that is accessible and safe to the consumer and sustainable for the provider". Nevertheless, to analyze the level of financial inclusion globally, four key elements are inherent in all these definitions, namely:

- **Accessibility:** Consumers access financial products easily via physical branches and digital devices;
- **Diverse and appropriate products:** Financial products and services are tailored to meet consumer needs and can be readily selected and utilized as required;
- **Commercial viability and sustainability:** Financial providers offer profitable and sustainable products, services, or models, striving for balanced economic, environmental, and social impacts through efficient management;
- **Responsibility and safety:** The policy of financial inclusion should align with those of financial stability and market integrity.

Globally significant progress has been made in expanding the scope and ambition of financial inclusion, with China achieving remarkable results. According to the Global Findex Database 2021[10] and as illustrated in the graphs below, over the past decade, euro area bank account ownership has risen from 90% to almost 99% of adults and from 40% to 71% in developing economies (fig. 3). China mirrored this upward trend, from 64% to nearly 89% of individuals owning a bank account. Furthermore, a similar upward trend is observed in the usage of digital payments. In the Euro Area, the percentage of adults who made or received a digital payment increased from 88% in 2014 to 97% in 2021 (fig. 4). This trend is also evident in developing countries, including China, where COVID-19 served as a catalyst for this growth. Indeed, 82 percent of chinese adults made a digital merchant payment in 2021, with 11% doing it for the first time since the beginning of the pandemic. However, the progress in financial inclusion is not yet complete. Based on these statistics, most individuals who can easily open a bank account have already done so. Thus, the next steps are:

- Enhancing inclusive financial policies to connect rural customers with the internet, government, and the private sector;

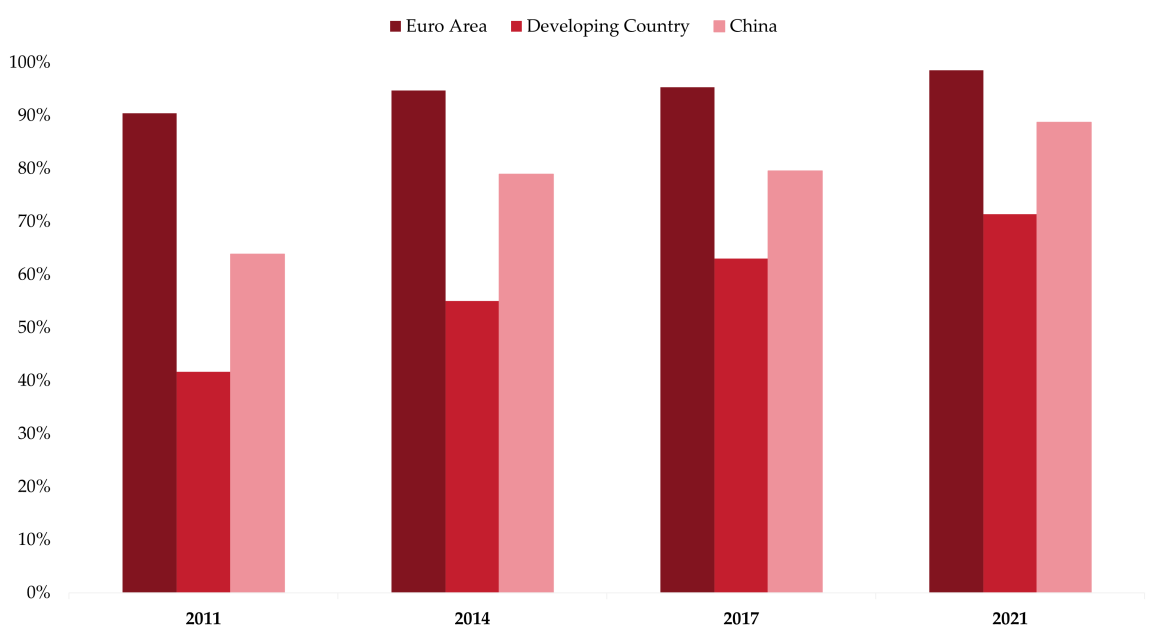

FIGURE 3: Accounts (% age 15+)

- Improving the range and quality of financial services available to those who already have a bank account.

Three key players have shaped and will continue to shape financial inclusion in China. Firstly, the fintech companies, led by two of the world's largest holding groups: Tencent and Alibaba. Through their e-commerce and fintech companies, they have introduced numerous financial innovations. Secondly, traditional financial service providers, which often maintain a focus on offering standard products to their customers. Finally, the Chinese government with PBOC and other financial sector authorities, whose policies govern the behaviors of the other stakeholders. Policies can support the actions of other stakeholders or take a different direction, as demonstrated by the development of a Central Bank Digital Currency (CBDC). In the following sections, there will be a more in-depth exploration of the topics discussed:

- Section 2.1 outlines the Chinese landscape that facilitated the rapid diffusion of digital payments and e-CNY;
- Sections 2.2 and 2.3 explore the government's solution to financial inclusion, digital renminbi;
- Section 2.4 includes a brief conclusion.

2.1 Chinese Landscape

Why is China so advanced in the development and use of new digital payment methods? Why does financial inclusion appear to be more progressed in China compared to other countries? As previously mentioned, the case study of the e-CNY is unique within the panorama of CBDCs due to its advanced stage of development and its reach to millions of citizens. Thus, what are the reasons for this upward trend? First, it is necessary to give a detailed description of the Chinese social structure, what are the main stakeholders and how are they characterized. The main stakeholders that shaped the financial inclusion in China are:

- **Chinese citizens.** They are the first utilizers of technological innovations, such as digital finance or e-CNY. Their characteristics and their needs are the reasons for the evolution of new digital payment methods or for better policies.
- **Chinese regulators and authorities.** Since the establishment of rural credit cooperatives in the early 1950s, the Chinese government and the People's Bank of China (PBOC) have consistently

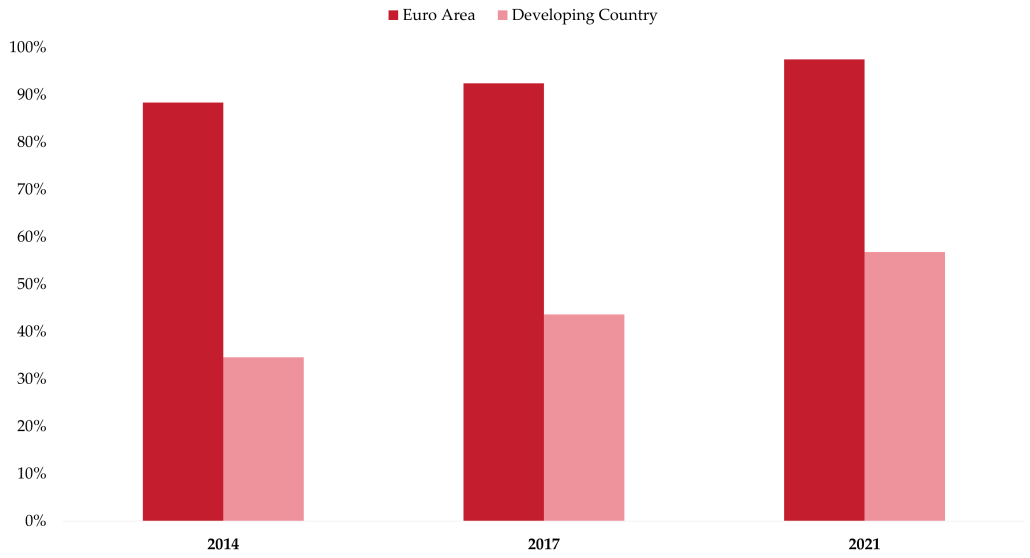

FIGURE 4: Made or received a digital payment (% age 15+)

Features	Indicators	China	Developing country	Euro area
Gender gaps	Male	89.92 %	74.20 %	98.70 %
	Female	87.34 %	68.47 %	98.31 %
Income distribution	Poorest 40%	83.08 %	66.55 %	97.38 %
	Richest 60%	92.46 %	74.59 %	99.25 %
Education level	Primary or less	83.02 %	64.76 %	96.54 %
	Secondary or more	97.21 %	78.99 %	98.93%
Age group	Ages 15-24	88.47 %	61.87 %	94.85 %
	Age 25+	88.91 %	74.22 %	98.98 %
Employment status	Out of labor force	69.10 % (2017)	56.49 %	97.84 %
	In labor force	83.41 % (2017)	70.30 %	99.03 %
Total		**88.71 %**	**76.20 %**	**98.51 %**

TABLE 1: Accounts per demographic classes (% age 15+)

focused on expanding access to financial services for their citizens. However, this heightened attention has recently led to the implementation of restrictive policies, particularly targeting specific subareas such as online lending and consumer loans[30]. Nevertheless, the most significant advancements in financial inclusion have been realized through the development and utilization of the People's Bank of China's CBDC, e-CNY.

- **Financial services providers.** Traditional providers such as banks, along with new types of providers like microcredit companies and fintech firms, serve as the driving force behind financial inclusion by offering competitive and innovative financial solutions. In this context, Alipay and WeChat emerge as the predominant players, boasting a collective user base of nearly 2 billion individuals in 2018[19]. Alipay holds approximately 50% of the market share in China, while WeChat Pay 40% [14].

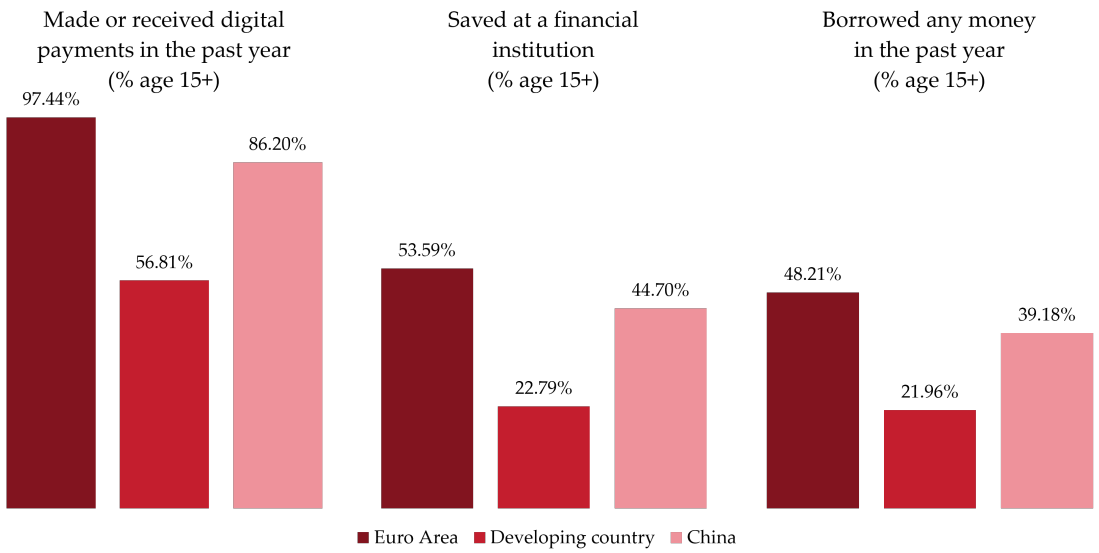

FIGURE 5: Other metrics

2.1.1 Chinese Citizens

With almost 1.5 billion citizens, China is the second most populous country in the world[39]. This, coupled with a low population density of 152 people per km^2, results in a significant divergence between urban and rural areas. In fact, in 2023, 35% of all Chinese citizens lived in rural areas rather than in cities. Moreover, despite boasting a high level of nominal GDP, the average wealth of Chinese citizens is not commensurately high, with a GDP per capita of $11,449 in 2022[40]. Nonetheless, the country demonstrates consistent improvement annually and could be categorized as an emerging economy. This demographic and economic landscape provides essential context for understanding the state of financial inclusion in China. The table above (tab. 1) presents statistics from the 2021 Global Findex database[10] on individuals owning a bank account, categorized by geographical region and various demographic characteristics. First, as stated in the previous section, China has already achieved a high level of overall accessibility to bank accounts which is way better than developing countries. However, compared to the Euro Area, there is still room for improvement. Significant disparities still exist particularly in income distribution, education levels, and employment status. Thus, it suggests that enhancing access to financial accounts for low-income individuals and those with only primary education or less will contribute to the overall progress of financial inclusion in China. Beyond account ownership, several other critical indicators of financial inclusion are depicted in the histograms above (fig. 5), which are derived from the Global Financial Inclusion Database. The first graph focuses on digital payment transactions. According to the Global Findex Database, making digital payments includes respondents who reported using mobile money, a debit or credit card, or a mobile phone to make a payment from an account, as well as those who used the Internet to pay bills or make online purchases within the past 12 months. Notably, a high share of Chinese citizens (86.2%) use digital payments, possibly due to the popularity of e-commerce, though this percentage is still below that of the Euro Area. The second graph illustrates individuals' saving habits, particularly savings at financial institutions. The data reveals that nearly 1 in 2 Chinese citizens (44.7%) saved at a financial institution at least once in the past 12 months, which is double the rate compared to developing countries. Finally, the last histogram presents borrowing behaviors of individuals over the past 12 months. Chinese adults are more likely than those in developing countries to report having borrowed in the past year but are significantly less likely to have done so compared to adults in the Euro Area.

2.1.2 Chinese Regulators and Authorities

China's financial inclusion landscape has evolved through different policies ruled by various Chinese regulators, such as the government and the PBOC. The creation of rural credit cooperatives (RCCs)

in the early 1950s set the start for an explicit financial inclusion policy. However, by the early 2000s, the effects of marketization and financial sector reforms had resulted in the closure of tens of thousands of financial service providers in rural areas. This left rural credit cooperatives (RCCs) and the postal savings system as the primary sources of financial services for rural residents. Moreover, at the 2006 National People's Congress, these problems were encapsulated and emphasized by the Three Rural Issues (agricultural, rural, and farmers' issues), or sannong, which highlighted the economic challenges faced by peasants in rural areas since 1990. Therefore, Chinese financial sector authorities began to focus on three main areas:

- Universal access to basic banking services;
- Productive credit for rural households;
- Bank credit for micro and small enterprises.

To achieve these objectives, the China Banking Regulatory Commission approved the creation of the Postal Savings Bank of China (PSBC) in 2007, a full-fledged state-owned commercial bank [9]. Its goals were to promote financial inclusion by deploying agent-based service points and adapting services to meet the diverse needs of rural consumers. Nowadays, the PSBC offers a variety of financial services, including minimum livelihood guarantee payments, grain subsidies, rural medical insurance subsidies, utility payments, remittances, e-commerce services, loan applications, and investment counseling. This makes PSBC the most broadly represented financial service provider in rural China[27]. Simultaneously, another state-owned commercial bank was founded in 2009[35], the Agricultural Bank of China (ABC). The bank has been at the forefront of implementing the government's three-pronged policy aimed at supporting the agricultural sector, rural communities, and farmers (sannong). In recent years, ABC has made significant advancements in product and service innovation to better serve these areas. For example, ABC developed various nonland-related collateral, such as farming equipment, agricultural inventory, and direct grain subsidies, to facilitate secured lending in rural areas. It is important to mention the China Banking Regulatory Commission (CBRC), established in 2003[26] to regulate China's banking sector. In 2018, it merged with the China Insurance Regulatory Commission (CIRC) to form the China Banking and Insurance Regulatory Commission (CBIRC)[26]. Additionally, the CBRC, in collaboration with the People's Bank of China (PBOC), has organized and supported numerous outreach, training, and knowledge development activities related to movable. finance product development, often in partnership with the World Bank Group's International Finance Corporation (IFC). In addition to these regulatory authorities, the Chinese government together with the central bank, PBOC, also have actively taken a wide range of policy measures to promote financial inclusion, through monetary and credit policies, tax policies, and supervision policies. More in detail, PBOC has encouraged financial service providers to extend credit services to rural communities (sannong) and micro and small enterprises (MSEs) through a range of policies, including differentiated reserve ratios, loan refinancing, and rediscounted loans. Finally, in 2015, the State Council issued China's Plan for Advancing the Development of Financial Inclusion (2016-2020) (FIP), which reaffirmed certain policy objectives aimed at advancing financial inclusion.

2.1.3 Financial Services Providers

The last significant social stakeholders in the Chinese financial inclusion landscape are the financial service providers, as summarized in the table below(tab. 2). Depending on their nature, each provider can be categorized into one of these three types:

- **Traditional financial services providers** (e.g. commercial banks, rural credit cooperatives);
- **New type providers** (e.g. village and township banks, microcredit companies);
- **Fintech companies** (non-bank digital payment providers, P2P lenders and internet-based financial services).

Traditional financial service providers. Have been pivotal in advancing financial inclusion in China. Under policy guidance from the Chinese government, these providers have greatly extended the

Category of Financial Service Provider	# of Providers	Total Assets (Billion Usd)	Total # of Branches	Regulator
State-owned commercial banks	5	12990	68953	CBRC
Joint-stock commercial banks	12	6521	15366	CBRC
City commercial banks	134	4236	16156	CBRC
Rural Commercial Banks (RCOMBs)	1114	3040	49307	CBRC
Rural Cooperative Banks (RCOPBs)	40	65	1381	CBRC
Rural Credit Cooperatives (RCCs)	1125	1193	28285	CBRC
Insurance companies	203	2268	-	CBRC
Village and Townships Banks (VTBs)	1443	186	-	CBRC
Microcredit companies (MCCs)	8673	-	-	Local government
Nonbank digital payment providers	266	-	-	PBOC
P2P lending platforms	3709	-	-	CBRC

TABLE 2: Financial Service Providers

physical reach of their service networks, modernized the country's payment infrastructure, and introduced product-level innovations, often through partnerships with fintech companies. Consequently, there has been a substantial increase in the adoption and usage of financial products, particularly bank accounts and bank cards. One example is the Rural Credit Cooperatives (RCCs). Starting from 1950s, RCCs have undergone various reforms over the years, the most significant occurring in 2003 when RCCs were no longer required to maintain their cooperative ownership structure, governance, or business operations. This reform led to the creation of two new institutional forms: Rural Commercial Banks (RCOMBs) and Rural Cooperative Banks (RCOPBs). By the end of 2016, 1,125 RCCs were operating in China, along with 1,154 RCOMBs and RCOPBs that had transitioned from RCCs following the 2003 reforms[32]. However, several challenges continue to limit RCCs' role in financial inclusion, including poor governance, small customer bases, excessive local authority interference, and limited capacity for innovation. Consequently, RCCs are losing appeal in favor of new fintech companies.

New type providers. Between 2006 and 2008, the Chinese government introduced regulations to establish "new type" rural financial service providers, including village and township banks (VTBs), rural mutual credit cooperatives (RMCCs), and microcredit companies (MCCs). The policy objective was to increase financial inclusion among traditionally underserved and unserved customers. Establishing these new rural providers can be seen as an extension and complement to ongoing efforts to strengthen the role of RCCs in serving the agricultural sector, rural communities, and farmers (sannong), as well as a mechanism to promote competition in rural financial services. These new-type rural financial service providers are characterized by differentiated and lighter requirements for registered capital, organizational structure, and ownership arrangements. According to the World Bank Group[32], these providers have had numerous positive effects. They have improved access to rural finance, filled gaps in financial services in rural areas, and reduced farmers' and micro and MSEs' reliance on civil society finance, thereby enhancing the financial environment in rural regions. Despite these positive outcomes, challenges remain, such as limited innovation, high management costs for VTBs, and MCCs' limited differentiation in market positioning from commercial banks.

Fintech companies. The most recent actors in Chinese financial inclusion are the emerging fintech companies. In recent years, China has become a global leader in fintech innovation. New entrants to the financial sector have introduced novel models, delivery channels, and products, leveraging the massive scale and network effects of online e-commerce and social media platforms. The rapid growth of fintech companies in China can be attributed to their ability to meet the unmet demand from consumers and micro and small enterprises (MSEs) that were often overlooked by traditional financial service providers focused on state-owned enterprises. Additionally, the proliferation of

fintech in China has been fueled by advancements in technology, such as the Internet, smartphones, digital payments, Artificial Intelligence, and Machine Learning, along with initial promotion and legitimization by the Chinese government and institutions, with a "wait and see" approach. However, Chinese regulatory authorities have recently become more restrictive, issuing targeted regulations to ensure safe and supervised innovation, along with a more centralized financial power. This results in more restrictive entry barriers for new companies and consolidates the position of early movers. Two of the most significant early movers are Ant Financial Group and Tencent Holdings Limited. These large financial groups own various entities operating in the fintech sector. For instance, they own the top two nonbank digital payment providers with the highest payment volume in 2019: Alipay and WeChat Pay[30]. Additionally, they offer other internet-based microlending services, such as Ant MCC, which provides small loans to agricultural households in rural areas, and internet banks like WeBank and MYBank. With this wide range of different financial services, Ant Group and Tencent hold dominant positions in China's digital finance sector and both companies have significantly expanded financial inclusion. However, recent regulatory actions, such as the mandated separation of Jiebei and Huabei services into distinct corporate entities[15], may significantly undermine their influence in digital finance. These regulations are issued to prevent financial instability that could arise from such a duopoly, which might lead to increased transaction costs or higher credit and investment fees, anyway, thanks to the collaboration and efforts of these stakeholders, China has emerged as a global leader in digital payments.

2.2 Digital Renminbi for Financial Inclusion

Another approach the Chinese government adopted to foster financial inclusion in the country is the development of the digital Renminbi, e-CNY. It also intends to support fair competition, which is mainly dominated by the duopoly described before. Furthermore, with the decline in cash usage for retail payments due to the rise of the digital economy and cryptocurrencies, a new state-based digital currency with a legal tender could offer greater safety, universality, and inclusivity for citizens. The digital RMB system is designed to further lower the barrier to public access to financial services compared to alternatives like Alipay and WeChat Pay. For instance, it operates without requiring a bank account and does not necessitate KYC (Know Your Customers) procedures for small amounts of e-CNY. Moreover, because its operations are governed by the state, cannot be negatively affected by new regulations. Finally, another crucial advantage is the absence of interest charges for using e-CNY as a means of payment. Anyway, MyBank and WeBank announced their plan to incorporate e-CNY as a payment option on their platform, enhancing interoperability between these major providers[15]. More details about the digital renminbi app and its functionalities will be provided in the next chapters. Thus, the full rollout of e-CNY offers several key benefits:

- **Increased interoperability.** Both Alipay and WeChat Pay could integrate e-CNY into their wallets, enhancing the compatibility between various intermediaries;
- **Enhanced financial security.** In the event of major disruptions among intermediaries, the PBOC can ensure the payment system remains operational;
- **Broader accessibility.** e-CNY enables digital payments in areas with physical and social barriers;
- **Issuing subsidies.** e-CNY can be utilized to distribute state subsidies directly to the accounts of citizens requiring financial support.

On the other hand, there are significant concerns regarding the potential negative implications of e-CNY on financial inclusion in China. First, despite numerous regulations aimed at limiting other financial service providers, the duopoly of Alipay and WeChat Pay still maintains substantial market share and influence. These platforms can now extend their reach to unbanked individuals, potentially offering additional financial services that may not be necessary. Second, it remains uncertain how much rural areas and citizens will benefit from e-CNY. Although, according to ABDInstitute[15], some rural citizens still lack of bank accounts and/or a stable internet connection. Third, the legal and regulatory framework for financial consumer protection requires further adaptation to ensure comprehensive coverage of consumer protection risks associated with fintech and digital finance. Specifically, there is a critical need for a robust legal framework for data protection and privacy.

2.3 Chinese Financial Inclusion: Conclusions

The Chinese financial inclusion landscape has flourished, thanks to the concerted efforts of all stakeholders. First, the role of the government and regulators has been pivotal. Implementing a robust and comprehensive financial ecosystem is essential for enabling financial inclusion. The government initially adopted a "wait and see" regulatory approach to foster the development of new digital finance models, which were subsequently actively monitored to mitigate consumer risks. Second, financial service providers have significantly contributed to financial inclusion. Traditional providers, following government policies, have expanded their networks and modernized payment infrastructure, though challenges such as limited innovation capacity remain. New-type providers have improved access to finance in rural areas but faced high management costs. Emerging fintech companies, led by Ant Financial and Tencent, have utilized technology to meet the demand from underserved consumers and small enterprises. However, recent regulations aimed at maintaining financial stability may limit their influence. In conclusion, despite these challenges, China's coordinated efforts have positioned it as a global leader in digital payments and financial inclusion.

3. The Architecture of the Digital Renminbi

3.1 Two-Tier Model Analysis

Deepening the CBDC architecture topic is crucial to fully understand the different relationships between Central Banks, Commercial/Retail Banks, and end-users (e.g., consumers, small/medium businesses, and large corporates) while identifying the flow of information and legal claims amongst the multiple entities. Focusing on how the architecture of the digital Renminbi is designed, it is possible to note how it is to all intents and purposes an indirect architecture, consisting precisely of 2 main tiers. Going into more detail:

- On the first tier, the PBOC will issue and redeem e-CNY to commercial banks and other permitted organizations, including telecommunications corporations and already-existing mobile payment systems (Alipay and WeChat Pay). Among the responsibilities of the PBOC are wallet ecosystem management and digital currency issuance and disposal. This makes the e-CNY legal tender. As a result, the People's Bank of China Law has been amended to implement this management structure, extending the legal tender of the physical Renminbi to its digital form and emphasizing the PBOC's exclusive right to issue the Renminbi.
- Instead, the second layer consists of commercial banks and other approved institutions in charge of providing e-CNY to the general population. To be more specific, the authorized operators work together to jointly provide e-CNY circulation services and retail management under the PBOC's quota management. This includes innovative payment product design, system development, scenario expansion, marketing, business processing, operation, and maintenance.

Accordingly, to this system infrastructure, users must reach commercial banks in order to get e-CNY via a digital wallet; by doing this, PBOC is able to avoid becoming an intermediary in the Chinese financial system. It also lessens its obligations and risk exposure in this manner as well. Moreover, to fully harness the energy and inventiveness of all parties engaged and preserve the stability of the financial system, the PBoC will work to guarantee that there are fair playing conditions and that the market has a crucial role in how resources are allocated. In fact, this two-tier operating model may effectively leverage the resources, skills, and technological advantages of designated operators to achieve market-driven, innovation-promoting, and competitive selection of the best.
In addition, for what concerns the operating system, the digital Renminbi includes four different mechanisms[2]:

1. **Issuance**
   The issuance mechanism is the first one to be implemented. It starts with the commercial banks that must apply to the central bank in order to have their applications for digital RMB approved.

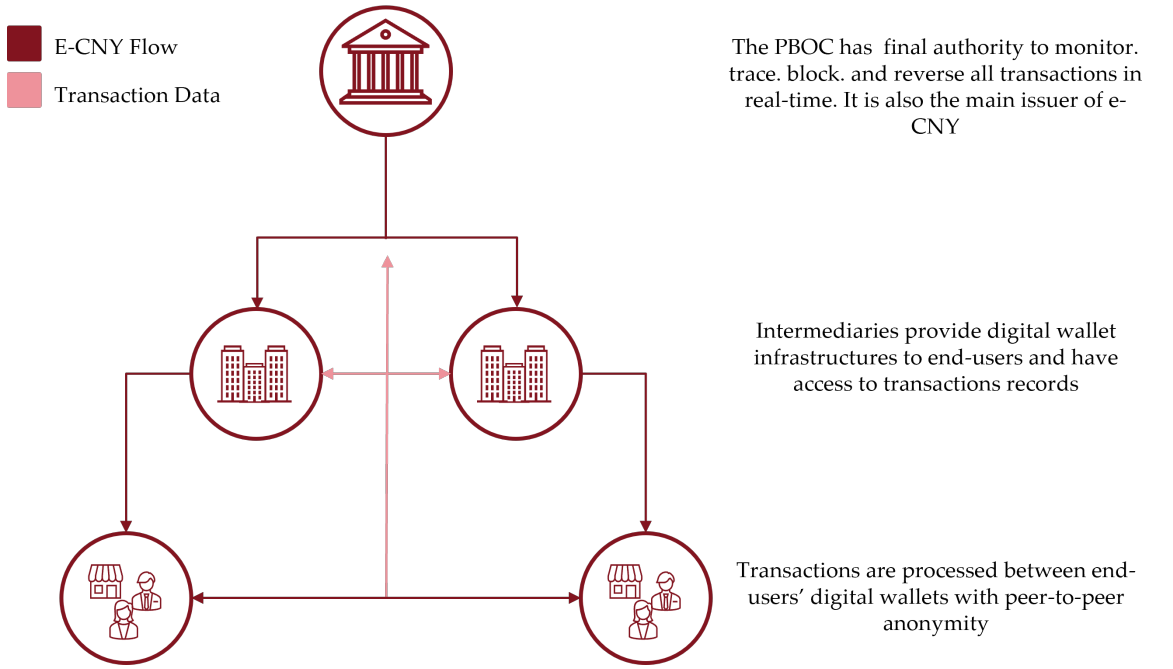

FIGURE 6: Explanation of the two-tier architecture of the Digital Yuan, [15]

The commercial banks apply to the central bank, which carries out uniform monitoring and approval of such applications. Consequently, the accounting system department will deduct the commercial banks' deposit reserves.

2. **Repatriation**
   Through the digital RMB repatriation mechanism, the central bank receives the digital RMB deposited by the commercial banks. It then deposits the amount and performs several storage or cancellation operations. Following the commercial banks' submission of an application for a digital RMB deposit, the central bank completes the ensuing approval order and partially completes the cancellation process. Then the accounting system department starts the deposit reserve increase command and deducts the corresponding amount from the reserve ratio. After the completion of these activities, it notifies the commercial bank that the return has been completed.

3. **Transfer**
   Moving on, the digital RMB transfer mechanism describes how digital RMB can be moved from one commercial bank, A, to another, B. The central bank will complete the subsequent nullification plan after bank A submits the transfer request. Based on the amount of money to be transferred, commercial bank B will generate RMB legal tender coins. If after the coins are nullified, there is still a balance of such coins, the central bank will realize the remaining amount and send the RMB legal tender coins to commercial banks A and B, respectively.

4. **Settlement**
   The last kind is the digital RMB payment mechanism, wherein the user primarily transfers digital RMB using a digital RMB wallet and wherein the transaction records from the data nodes are stored at the central bank data center. Furthermore, if the payer and the receiver are both offline the e-wallet records the transaction procedure to proceed with the transaction at a later time.

The latter mechanism gives an idea of the crucial role played by the digital wallet, the importance of which will be analyzed and explored in more detail in the following chapter.

	Cat.1	Cat.2	Cat.3	Cat.4	Cat.5
Sign up	In person	Remote	Remote	Remote	Remote
Authentication	ID and phone number	ID and phone number	ID and phone number	E-mail and phone number	E-mail and foreign phone number
Connected account	Yes	Yes	No	No	No
Balance limit	None	500.000	20.000	10.000	1.000
Transaction limit	None	50.000	5.000	2.000	500
Daily limit	None	100.000	10.000	5.000	1.000
Annual limit	None	500.000	100.000	50.000	10.000

TABLE 3: Digital Wallets: Types&Features

3.1.1 Technical Specifications

In this section, a deeper analysis of the e-CNY technical specifications will be conducted. Specifically, it is possible to state that, although some of the PBOC partners may decide to use distributed ledger technology (DLT), the e-CNY adopts a technology-neutral distribution. Indeed, the e-CNY can be transferred via digital data strings and has a variable face value, acting as a currency alternative. Tencent's (WeChat Pay) and Alibaba's (AliPay) proprietorial technologies form the foundation of its digital payment infrastructure. These make use of digital wallet-connecting QR codes. The customer shows a QR code on their phone upon payment, which the retailer scans to validate the transaction. Subsequently, funds are moved from the user's virtual account to the merchant's account. The retail CBDC can benefit from the QR code technique. This is because a buyer needs to obtain a form of payment and have it approved at the time of sale for a transaction to be completed effectively. After that, there needs to be a money exchange (in digital form) with the vendor. It must also be possible for the seller to utilize it as payment in subsequent transactions. The hybrid technical foundation of the e-CNY is based on the existing Chinese retail QR infrastructure. It makes use of distributed infrastructure and the digital wallets and QR codes discussed before. The framework is defined as follows[6] :

- **Hybrid technical framework:** The technological foundation for the e-CNY is hybrid. Its distributed infrastructure from its Tier 2 banks is combined with a Tier 1 centralized architecture. It is possible to co-develop functionality with this support for both an agile and steady state.
- **Distributed Infrastructure:** Decentralized payments are made possible by the distributed infrastructure of Tier 2 banks, which uses DLT protocols to provide simultaneous access, validation, and record-keeping. The Tier 2 banks use their computer network and several nodes or sites, usually connected via the Internet, to accomplish this.

3.2 The Digital Wallet

A pivotal role in the architecture of a CBDC is played by the digital wallet as it composes the primary interface between the digital currency and the end user. The Public Bank of China (PBOC) is responsible for stating the rules related to the whole set-up of a wallet eco-platform, based on centralized management, unified cognition, and anti-counterfeiting. Specifically, they authenticate e-CNY and realize wallet ecological platforms to qualify special features in order to satisfy the different types of demands of different users at different levels. On the other hand, according to the two-tier organizational system built up for the e-CNY, authorized operators jointly develop and share apps on mobile devices.
These intermediaries detain the digital wallets, and they categorize them according to the strength of the customer's identification and his necessities. e-CNY wallets are stored in the home-banking apps of such operators and users can reload their portfolio directly from them. These movements of cash clearly depend on the information obtained by the intermediaries related to the owner of the

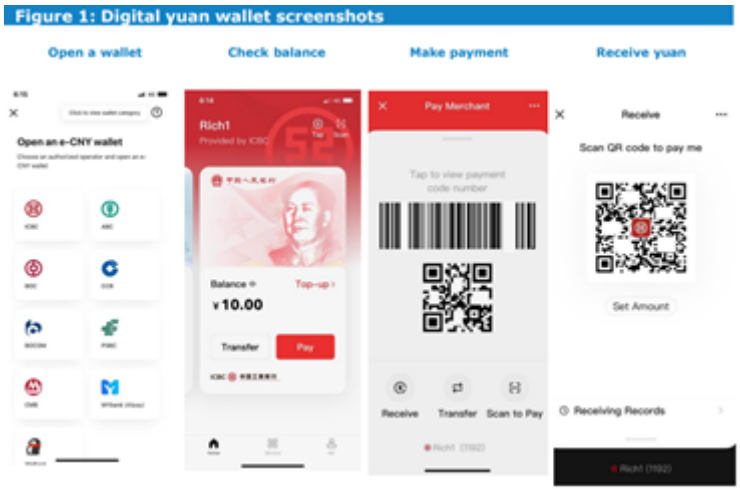

FIGURE 7: Four screenshots of digital yuan wallet interface[7]

wallet regarding his financial reliability. By default, users open anonymous wallets with the lowest privileges, which can be upgraded to real-name wallets with higher privileges as needed[11].
With the aim of a rapid and successful spreading of the digital currency, these wallets need to be user-friendly and furthermore to be accessible to everyone, also to the less acknowledged people. For this purpose, the wallet's interface resembles many popular contemporary digital payment apps in China, such as Alipay or WeChat Pay. Typical features already used for the above-mentioned applications such as QR code scanning or biometric authentication may become the usual practice also for the e-CNY wallet authentication and the approval of the transactions between them. It will be also possible to transfer digital yuan from one wallet to another by simply touching two phones together. On the strength of the fact that e-CNY is generated directly by the PBOC (and so it is considered legal tender), every type of transaction that involves the digital yuan must be accepted and this currency carries settlement finality, which means that payments made using the digital yuan are settled upon payment. In addition to that, payments in digital yuan may be preset in time in a similar way that happens with credit cards (i.e. through application programming interfaces).

3.2.1 Main Characteristics

Regarding the functionality of the transactions, a digital wallet exploits security chips and other technologies to enable the functions of e-CNY. These wallets are based on Integrated Circuit (IC) cards[2] and they may be supported by mobile phones, wearable objects or other Internet of Things devices.
Other important characteristics that could increase the appeal of such a wallet are the ability to merge with the already existing financial platforms[3] by including the connection to investment portfolios or permitting automatic bill payments; insertion of regulatory functions suggested by regulators directly into the wallet, i.e. automatic tax deductions, constant monitoring in order to avoid possible frauds or compliance with international sanctions. Moreover, these wallets may add multiple secondary functionalities to their basic backbone such as insurance products or microlending. As a consequence, this would lead to a larger offer and range of opportunities by commercial banks.

3.2.2 Loosely Coupled Account Links

Probably, the most relevant feature is the feasibility of transactions happening between two e-CNY wallets without the need for them to be associated with a bank account or to be connected to the Internet. The PBOC refers to this particular system as loosely coupled account links which

[2]An IC (Integrated Circuit) card is a payment card, typically made of plastic, that incorporates an embedded microchip to store data, replacing or complementing the traditional magnetic stripe.
[3]Both Tencent and Alibaba have announced the integration of Digital Renminbi on their platform, which are respectively WeChat pay and Alipay.

	June 2021	October 2021	December 2021	May 2022	August 2022	June 2023
Personal wallets	20.87 Mln	140 Mln	261 Mln	n/a	n/a	120 Mln
Corporate wallets	3.51 Mln	10 Mln	n/a	n/a	n/a	n/a
Transaction numbers	70.75 Mln	150 Mln	n/a	264 Mln	360 Mln	950 Mln
Transaction value	RMB 34.5 Mln	RMB 62 Bln	RMB 87.6 Bln	RMB 83 Bln	RMB 100.04 Bln	RMB 1800 Bln
Avg Transaction value	RMB 488	RMB 413	n/a	RMB 314	RMB 278	RMB 1895

TABLE 4: *e-CNY Pilot Statistics[20]*

was designed primarily to make e-CNY function more like cash and so, as said before, to ease the dissemination and use of the digital currency even for that slice of the population that is less technologically savvy.
As stated in PBOC's 'Progress of Research & Development of e-CNY in China' released in July of 2021, e-CNY claims "to meet the public demand for anonymous small value payment services based on the risk features and information processing logic of current electronic payment system[s]" This ensures that difficulties arising from technological illiteracy or geographical limitations are minimized to meet people's needs in order to create a structured but highly usable operational system that can secure business continuity. Therefore, this innovation in terms of transactions is aimed at building up a new and efficient financial framework without binding people to disengage too much from the usual payment systems they use in everyday life.
Thanks to this, offline and online transactions are both feasible. While the latter ones are obviously supervised by the PBOC who acts as a transaction validator, the possibility of offline settlements may lead to think that, for these specific cases, they can happen without any limits or regulation. However, this is not properly true: transactions are anonymous vis-à-vis third-party intermediaries, such as commercial banks and internet platforms, but the PBOC and other authorized entities can see them. This is called **manageable anonymity** since, from one side, the PBOC has still the right to increase or decrease the level of a transaction and even, if necessary, deactivate a wallet if illegal or just suspicious manoeuvres are detected, but, at the same time, some steps involving the online banking system are overcome. Despite that, the technical features related to the transmission of data are not fully disclosed yet to the Central Authority, so it is not known, as of today, how the entire process in offline transactions works.
A key mention has to be made to the different levels of anonymity depending on the weight of the transaction. To quote Mu Changchun[29] , the director of PBOC's Digital Currency Research Institute, "The anonymity of the central bank's digital currency is limited under the premise of controllable risks. However, it is possible to make small payments using anonymous wallets linked to cell phone numbers. To conduct digital yuan transactions of large amounts, consumers will have to undergo KYC (Know-Your-Customer) verification procedures." Small value payments can be conducted in a simple way without KYC standards while large ones require users to perform KYC.

3.2.3 Different Types of e-CNY Wallets

According to the information received by the authorized operators, different types of wallets are generated, and they can vary from user to user in, for example, the limits of daily transactions as well as a maximum balance. In this way, PBOC and the other entities involved can maintain an efficient control architecture and people who usually do not need to move large amounts of money can still keep a high level of privacy.
In the same way, users can customize their wallets to have functions that meet their needs and their financial possibilities. The effort put in by the PBOC to create tailor-made wallets for the customers is yet another attempt to build an easy-to-use scheme for all people.
In particular, digital wallets seem to have three key dimensions:

- **Software and Hardware**
  A main subdivision in the digital wallet architecture can be done according to how customers may access to them. In particular, software wallets provide services through mobile payment

apps, software development kits (SDK), application programming interfaces (API), and so on. On the other hand, a hardware wallet is based on security chips and other technologies in order to realize e-CNY-related functions. Such chips are supported by IC cards, cell phone terminals, wearable objects such as badges, bracelets, gloves, or smart watches, and the Internet of Things devices. This combination of hardware and software ensures that the whole wallet ecosystem is well-designed to grant the availability of the digital currency and to meet the wishes of different people.

- **Personal and Corporate**
  Digital wallets may differ also on the type of subject of their opening. Ordinary people and self-employed individuals can access to personal wallets whose strength is determined by the information collected regarding the subject (I.e. they may vary on transaction, balance, and daily limits). In a similar way, corporate wallets can be opened by legal persons or unincorporated organizations: in this case, the limits are calculated according to whether they are opened in person or remotely. There may be further possible customizations in order to suit the needs of the users: the hierarchy of these portfolios depends on how much information users want to provide (in case they want to make large amounts payments or keep higher balances).

- **Parent and Sub**
  An additional split refers to the possibility to set up a main wallet (which will be called parent) and open a few sub-wallets under it. These can be subject to payment caps, payment conditions, personal privacy protection, and other functions that can be set by customers. Furthermore, sub-wallets may be exploited by enterprises and organizations to distribute their funds and manage their finance in the most efficient way. The opening of sub-wallets is encouraged by e-CNY: through the use of tokenization and encryption, online merchants such as e-commerce platforms or O2O (online-to-offline) can isolate their personal information from other tech companies and so protect users' privacy.

3.2.4 Digital Wallets in China: Statistics

The main focus of the People's Bank of China, together with the designated operators and all the relevant organizations, is creating a well-designed wallet architecture to meet the needs of multiple scenarios and perceive their own distinctive functions. The loose coupling between the e-CNY wallet and the bank account reduces the dependence on financial intermediaries in the transaction process and allows for anonymity for small-value payments.
In July 2023, Yi Gang, China's central bank governor, released an update on some statistics regarding the usage of e-CNY digital wallets among customers[20]. According to Mr. Yi, more than 20.87 million personal wallets have been opened by individuals and organizations and over 3.51 million corporate wallets, with transaction volume totalling 70.75 million and transaction value approximating RMB 34.5 billion given the first data collected in June 2021. Due to the shortage of information available, it was not possible to find any details related to the percentage of parent and sub wallets opened in the last years.
Further information was given related to the number of CBDC wallets, which should be around 120 million. Previous reports, actually, talked about 300 million wallets, so it is possible that Mr. Yi was speaking of active e-CNY wallets instead of opened ones.
Although the number of digital wallets seems to have decreased in time, the amount of transactions has hugely increased to 950 million along with the average transaction values which suggests that the usage in corporate cases had a considerable boost in the last few years (predictable since the Shanghai Clearing House announced it would support the digital yuan for wholesale commodities transactions).
Not only from the point of view of the architecture of digital wallets but in general for the whole CBDC structure, China seems to be the most developed and most advanced country, especially in contrast to Europe which still has great strides to make to reach the level of the Asian superpower.

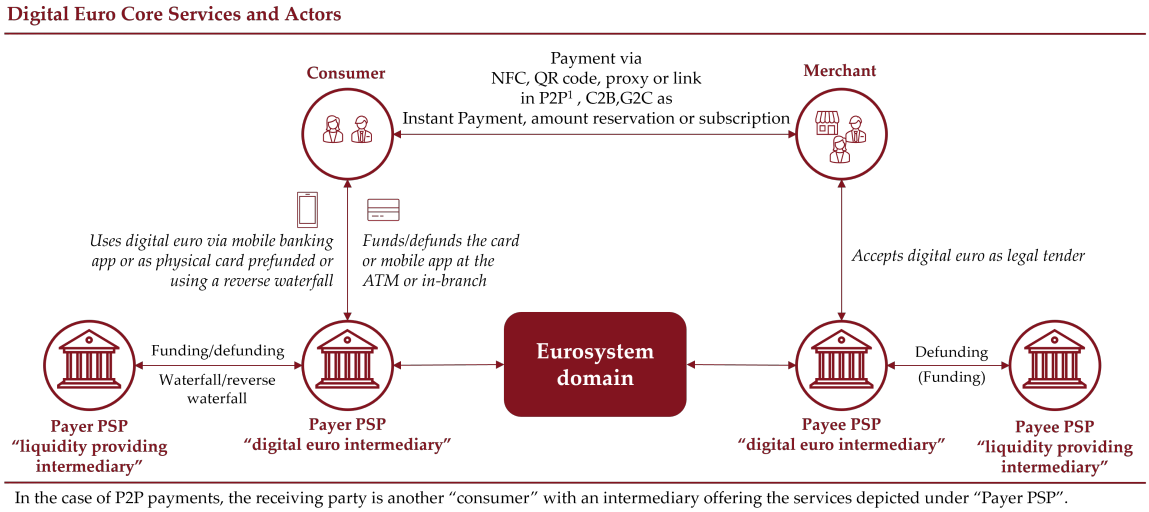

FIGURE 8: Main services and actors of Digital Euro[12]

3.3 Differences between the Digital Euro Scheme and the Chinese Model

According to what was initiated and seen in the previous paragraphs, the models taken as reference in our consideration find not only similarities but also obvious differences. These, in this regard, are particularly due to cultural and jurisdictional characteristics; about the structures on which these models rest, however, it is possible to find elements of similarity. We leave the examination of these aspects to the next lines of this section.
In order to deeply analyze the different keys of comparison, it's possible to set the aim of the discussion starting from and considering the following structure: *Background*, *Design*, *Functionalities*.

3.3.1 Background

Standing initially on considerations about the regulatory and perimeter background, clear differences between the two digital currencies in question appear. It is possible, in fact, basically to consider the earlier birth and the consequent greater development of the latter over the former, that is, of the Digital Renminbi over the Digital Euro; in this sense, standing on the main consideration of the normative perimeter publication, a White Paper on research and development has been issued during 2021, establishing the scopes and elucidating the PBOC's stance, the context, goals, and aspirations, outline the design framework, and address policy considerations concerning the e-CNY system. On the European side, since the origin of the concept in 2020, ECB has aimed to reduce this well-known gap with China as much as possible by establishing the preparation of ad hoc regulatory frameworks and initiating related study and development phases: after years of research, the ECB entered the Preparation Phase of the Digital Euro project in the last November (2023), phase in which has been stated and confirmed that the Digital Euro is expected to actually launch in 2027; in spite of this, dealing again with the e-CNY, its experimentation has already been conducted on individuals.

3.3.2 Design

In the present section, various elements of difference between the two currencies can be analyzed, albeit with some similarities in some aspects; it's possible to start with the general structures and the scopes. In this sense, just like the Digital Euro, the e-CNY is designed to reflect the functionality of physical RMB, serving as a direct claim on the central bank and backed by sovereign credit. Primarily catering to domestic retail payment needs, it operates, as already said, on a two-tier architecture, albeit with a not-so-clear infrastructure and access systems as per current public information. Notably, its design is attuned to mitigate the risks of financial disintermediation, hence devoid of interest and subject to quantitative limits through a tiered wallet mechanism.

The two-tiered (or indirect) structure represents an element of differentiation from the one implemented by ECB, which relies upon a "hybrid model" accepted by the European Commission in 2023; this assumes that the digital currency is directly issued by ECB, while the private sector provides its distribution and end-user relationship. Given this consideration, the Chinese model can still be considered as a kind of hybrid but is slightly diverging from the direct provision of consumer accounts by the central bank; in fact, the PBOC distributes the e-CNY to authorized and selected operators, such as commercial banks and other financial intermediaries, who will subsequently provide it to consumers along with exchange and circulation services. Despite seemingly amplifying the authority of China's Central Bank over commercial banks, this architecture does not entirely exclude commercial banks or private payment tools (like WeChat or Alipay).
With these infrastructure considerations being made, it is worth mentioning that its functional system substantially deals with blockchain technology, standing on a centralized methodology; even for this case, Eurosystem is currently exploring centralized and decentralized approaches, such as distributed ledger technologies but, however, a decision on this side has not yet been made. In particular, it could be mentioned that ECB conducted a prototype exercise from July 2022 to February 2023 in which has been tested the Digital Euro back-end prototype for online payments, known as NXT: differently from a distributed ledger, NXT's structure is based on a UTXO (Unspent Transaction Output) data model, a largely used instrument in digital currency transactions[23]. Continuing in the other sense, the e-CNY functions on a centralized-permissioned Distributed Ledger Technology (DLT) managed by the PBOC, which records and processes all transactions: this implies that the government has complete access to transaction data and retains the authority to annul or reverse transactions as deemed necessary.
On the other hand, this represents and opens a clear discussion point on the privacy issue; in particular, a few lines will be spent on this topic below. The position of the EU to protect users' privacy has been widely declared and, in this sense, we could find in it another element of diversity. Providers of e-CNY services use to classify customer information into "general" and "sensitive" categories. However, commercial banking policies often lack clear guidelines on handling sensitive e-CNY user data. While China's Personal Information Protection Law (PIPL) applies to digital currency service providers, the absence of specific operational procedures in commercial banks' pilot policies may create regulatory gaps in protecting sensitive e-CNY user information. Therefore, the use of e-CNY transactions does not offer complete anonymity, as the PBOC retains access to transaction data for security purposes; this lack of anonymity is due to currency registration and traceability being inherent in e-CNY transactions. The People's Bank of China can exercise comprehensive oversight over the currency's usage through data mining and big-data analysis. However, the effectiveness of this oversight in controlling tax evasion, money laundering, and terrorism financing is questionable, as most illicit activities do not occur through formal monetary channels, as stated by Bank for International Settlements. On the other hand, although still in the formative stage, the European Data Protection Board (EDPB) clarifies that privacy rules will be extensively specified. It also notes that solutions will be adopted that, however, cannot guarantee complete transaction anonymity; therefore, to meet the privacy protection objective, "privacy thresholds" will be set, i.e., limits below which neither offline nor online low-value transactions are traced for anti-money laundering and counter-terrorism financing purposes.
The EDPB and the EDPS (European Data Protection Supervisor) emphasize that the proposed Regulation should further clarify the data protection responsibilities of the ECB and PSPs: this includes the legal bases on which the ECB and PSPs should rely and the types of personal data they should process for the issuance, distribution, and use of the Digital Euro.

Another point of discussion stands now on the theme of interests' generation. According to this, the PBOC White Paper demonstrates a keen awareness of the potential hazards of financial disintermediation: for instance, the e-CNY neither accrues interest nor related payment, mitigating competition with commercial banks. Moreover, the e-CNY operates within a comprehensive framework encompassing big data analysis, risk monitoring, and early warning systems; while not overtly stated, this framework may imply a precautionary measure preventing withdrawals from commercial bank deposits into e-CNY during periods of financial instability. As far as Europe is concerned, it seems to be addressed on the same path: within the framework of its Regulation, the Digital Euro won't generate interest payments. In a parallel field, it's possible to present another

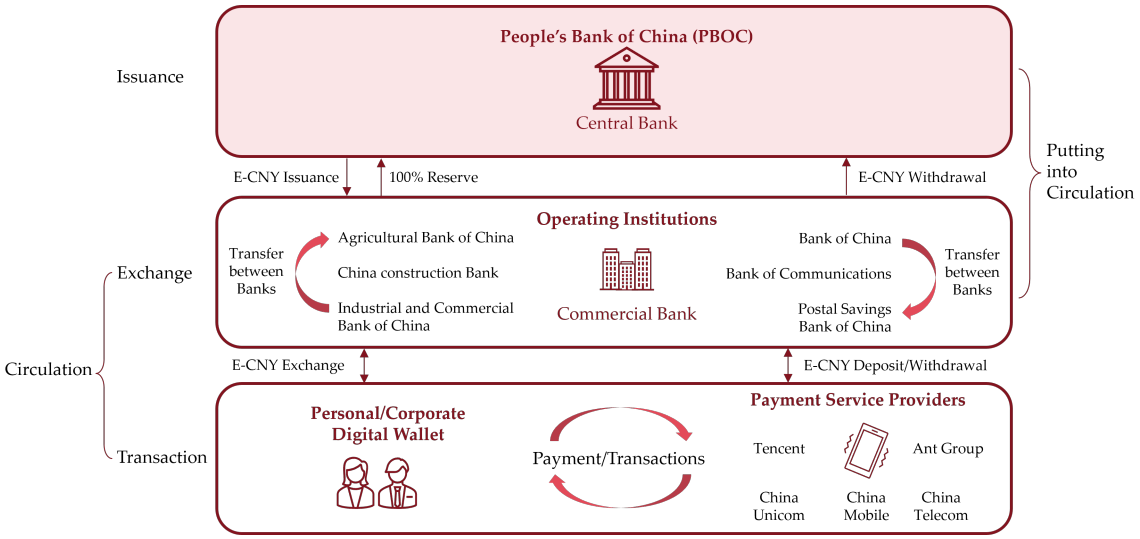

FIGURE 9: The e-CNY's Two-Tier Operating System [11]

similarity between the two currencies, reaching the topic of "internationalization". In this sense, ECB has announced that, following a success behind the launch of the Digital Euro in the Euro Area, it will commence studying and endorsing the technical feasibility of implementing cross-currency and cross-border functionalities, aiming for multiple objectives. Ultimately, even though it would be primarily intended for domestic use, the e-CNY is considered technically ready for cross-border transactions. In this field, the PBOC White Paper adopts a prudent stance regarding the potential utilization of the e-CNY in cross-border payments or for advancing RMB internationalization. Indeed, China has initiated a collaborative initiative with the Bank for International Settlements (BIS), along with Hong Kong, Thailand, and the United Arab Emirates, to explore cross-border CBDC transactions facilitating almost instant settlements beyond conventional payment infrastructures.
In closing the present section, it's added that the Digital Euro would be endowed with the status of legal tender thus requiring its mandatory acceptance in payments by all payees: in light of this, the Digital Euro should also be directly accountable as a liability for the ECB. This similarity further aligns it with the Digital Renminbi.

3.3.3 Functionalities

In initiating this section, the specific functionalities, though in some ways shared, between the two types of currencies will be discussed, analyzing their applications, their modes of use, as well as the actors involved. As a first point, it's possible to present that the e-CNY aims to address several key functionalities as outlined in its White Paper.
One crucial feature is that the e-CNY leverages "smart contracts" to enable programmable functionalities, ensuring payments adhere to predefined conditions or terms: the just said feature could potentially restrict transactions with certain entities, such as criminal or politically undesirable ones, and facilitate targeted macroeconomic policies. Additionally, another important feature is the implementation of a tiered system of wallets, as said before, managed by authorized financial intermediaries under PBOC guidance; these tiers have varying transaction and balance limits, preventing users from emptying their bank deposits into e-CNY wallets entirely. They may present also different characteristics, such as the typologies personal/corporate, software/hardware, or a parent/sub-wallet. In general, the digital wallet, accessible via the e-CNY app, is where users manage and store their e-CNY funds; some of its advanced features may require verification with a Chinese identity card.
In a very similar way, the Digital Euro wallets should work, in particular with the maximum limit allowable and the associated identity verification, requesting a Digital Euro Account Number (DEAN). In a more general key, the typology of users can be categorized as: individual consumers, businesses and merchants, financial institutions, governments/public entities. Here, following the investigation phase, the ECB has decided to limit the holding of Digital Euros, albeit not defining

precise quantitative amounts[23].
As slightly mentioned in the previous parts, on the first side, private citizens would face restrictions on the amount they can hold in their accounts, an amount expected in its dimension but still unknown. For commercial users, merchants, and public administrations, a holding limit of zero will be established with the completion of the actual preparation phase, preventing them from retaining Digital Euros in their accounts: here, this zero-holding limit will be enforced through the waterfall system that transfers any received Digital Euro payments directly to the entity's cash account; simultaneously, a reverse waterfall approach will fund Digital Euro payments directly from the entity's bank.
Concerning this topic, the ECB through its Digital Euro Scheme (DES) and Digital Euro Rulebook defines Access, Liquidity, and Transaction Management, sets of services and procedures to address Digital Euro end users, using waterfall approaches in funding and defunding wallets.
Dealing with DES, through the figure 10, it's possible to evaluate the net of stakeholders participating in the process.
Here it's necessary to mention the compensation model for the Digital Euro, a model that aims to strike a balance between providing sufficient incentives for Payment Service Providers (PSPs) to distribute the Digital Euro and ensuring adequate protection for end users.
In a parallel way, it's provided in the figure 11 a similar structure of actors' involvement for e-CNY.

Standing on the DES, it aims to maintain the Eurosystem's central role in issuing and managing the digital currency while allowing Payment Service Providers (PSPs) some flexibility in design choices to enhance digital solutions; in support of this, the ECB's Digital Euro Scheme Rulebook outlines three levels of services that intermediaries must offer: Core, Optional, and Value-added Services: Core Services, mandatory for user readiness, include payment instrument management and transaction processes; Optional Services, at the discretion of intermediaries, may include account portability and payment scheduling; Value-added Services, left to the private sector, aim to innovate and improve solutions for end users. On this last basis, it has already been observed that Chinese model leaves operational margin only for selected intermediaries, giving here another slight difference. In the will of mentioning one more point, on the side of payment programmability it is easier to find a clearer ground: China has already been active on this aspect for some time, while Europe is still in the evaluation phase, though it does not embrace an openness to it.
Wanting to conclude this section, it is possible to point out that according to what has been seen and analyzed, while there are several differences between both currencies, there are just as many elements that unite them; or rather, unite the Digital Euro with the Digital Renminbi. By virtue of this, clear as it may be, the e-CNY currently connotes itself as one of the most developed digital currencies in the world, to whose models even the Euro, in a sense, aspires. So, although the details of this discussion have been glossed over, the main difference would seem to be precisely the time elapsed between their respective adoptions.

4. The Technology Behind Digital Renminbi

4.1 Digital Currencies and Cryptocurrencies: Analogies and Differences

Digital Currencies, Cryptocurrencies and blockchain technology are tightly related yet are different things. In recent years, the landscape of finance and technology has undergone a transformative evolution, propelled by the rise of digital currencies, cryptocurrencies, and blockchain technology. These innovations have not only captured the attention of investors and entrepreneurs but have also sparked profound discussions about the future of money and decentralized systems. At the forefront of this revolution are cryptocurrencies, decentralized digital assets built on blockchain technology. Bitcoin, the first and most well-known cryptocurrency, emerged in 2009 as a decentralized alternative to traditional fiat currencies, challenging the existing financial paradigm controlled by central authorities. Cryptocurrencies are blockchain based digital currencies. Blockchain refers to a distributed ledger system that enables transparent, secure, and immutable record-keeping of transactions. Unlike traditional centralized databases, blockchain operates on a decentralized network of computers (nodes), where transactions are verified and recorded in chronological order. This decentralized architecture ensures that no single entity has control over the network, fostering

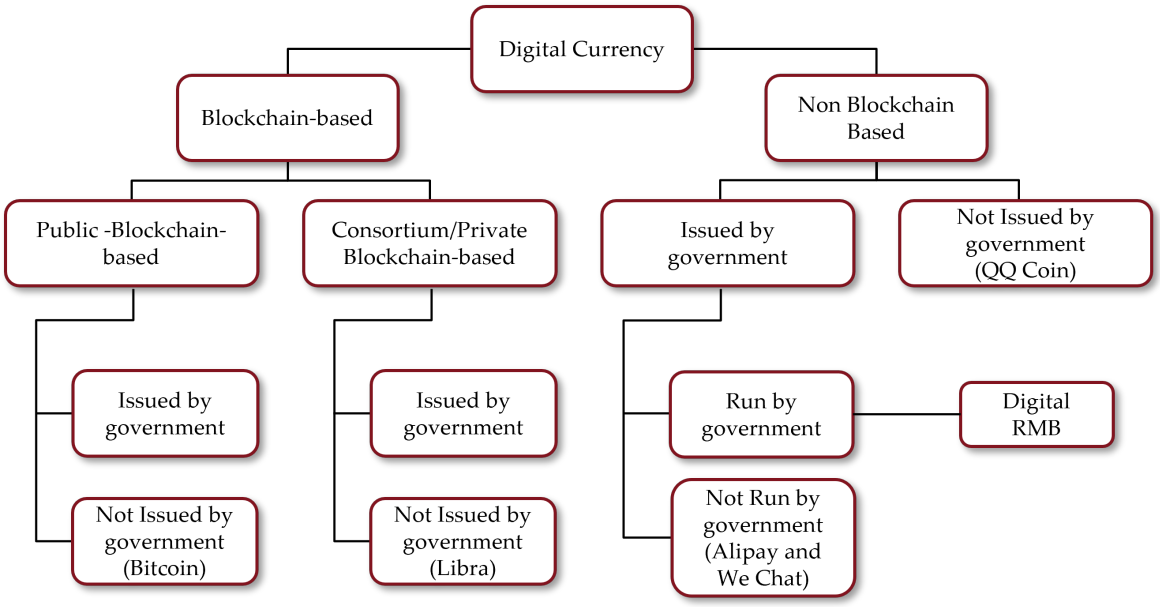

FIGURE 10: Categories of Digital Currencies

trust and resilience in the face of tampering or censorship. Moreover, public blockchains derive their sustainability from the computational resources contributed by miners, individuals, or entities whose primary aim is to acquire cryptocurrencies. These miners play a crucial role in the network's operations, dedicating their computing power to validate transactions and secure the blockchain. In return for their efforts, participants in most blockchain networks, excluding those privately owned, are rewarded with incentives to ensure the ongoing maintenance and integrity of the system. The incentivization mechanism within blockchain ecosystems typically revolves around the issuance of cryptocurrency tokens, such as Bitcoin and Ether, which act as rewards for miners and other network participants. These tokens serve not only as a form of digital currency but also as a mean to incentivize continued participation and contribution to the network's operation and security. However, it's worth noting that not all blockchain networks operate on this incentive model. A second framework typology involves privately owned blockchains, exemplified by IBM's Hyperledger. Such blockchains diverge from the traditional cryptocurrency-based incentive structure: in these cases, the maintenance and operation of the blockchain are overseen and managed by a central entity or organization, rather than relying on external participants seeking cryptocurrency rewards. Instead, the private owner of the blockchain assumes responsibility for its upkeep, ensuring its functionality and security without the need for external incentivization through cryptocurrency rewards.

The third category of digital currency operates independently from blockchain technology and involves utilizing internet-based transactions instead of traditional cash payments. This category encompasses various forms, including digital tokens utilized within online platforms. Examples of such digital currencies include those offered by Alipay and WeChat, and Tencent's online gaming communities (QQ Coin). While Apple Pay, a relatively recent addition to the digital payment landscape, incorporates cutting-edge technologies like Near-field communication (NFC), its payment methodology closely mirrors that of established platforms such as Alipay, WeChat, and PayPal. Apple Pay facilitates transactions by linking to users' bank accounts, thereby avoiding the creation of new currency.

4.2 e-CNY Technology

Ever since the first rumors of the digital currency from the People's Bank of China there were analogies to blockchain-based cryptocurrencies like Bitcoin, in reality such comparisons are far from justifiable, these instruments are indeed very different technology-wise. First of all, the purposes are very different, Bitcoin was built in 2009 with the intention of creating the first peer-to-peer currency that did not need any centralized authority to supervise its functioning; China on the other hand has

the goal of becoming the first major economy to integrate a central bank digital currency. Designed to serve as a digital, perfect substitute for physical money e-CNY had not been developed using the same technological framework of blockchain-based digital currencies for different reasons:

- A permissionless public distributed ledger or blockchain could not be scaled due the available technology to the need of China economy, such solution would not be appropriate to manage the expected transaction volumes. According to the People's Bank of China (PBC), the Digital Currency Electronic Payment (DC/EP) system must possess a processing capability of at least 300,000 transactions per second[28]. This requirement closely mirrors the peak processing capacity of Alibaba, which was demonstrated during Singles Day 2019[33]. On that occasion, Alibaba's Apsara Operating System successfully handled a staggering 544,000 orders per second. However, current blockchain technology falls significantly short of meeting this demanding criterion. For example, Bitcoin can theoretically process only seven transactions per second, while Libra boasts a more modest capacity of up to 1,000 transactions per second [21].

- The decentralized nature of blockchain technology presents a significant challenge to the centrality of the People's Bank of China (PBC) within the country's financial system. Furthermore, it has the potential to undermine the government's control over monetary policy through the central bank. For example, in a system utilizing Bitcoin technology, the money supply would be dictated by market participants rather than by the central bank. Similarly, in a scenario resembling a Libra-type consortium, the authority wielded by the consortium would effectively supplant that of the PBC, assuming the role of a de facto central bank.

- Furthermore, the adoption of a public blockchain would enable market participants to have unrestricted access to all data stored on the ledger, which would directly contradict China's Cybersecurity Law. This law explicitly mandates that data generated within China's borders must be exclusively stored and processed within the country. Consequently, the People's Bank of China (PBC) cannot authorize the exposure of DC/EP transaction data to any computer linked to the public blockchain.

The PBOC, considering the constraints of public permissionless DLT, has opted, according to the e-CNY architectural model, for a technology-neutral two-tier hybrid framework where:

- **Tier 1**: Rely on permissioned Centralized Ledger which guarantees the centralized settlement of the transactions and to PBOC "the full access to transaction data and can cancel or revert transactions when it deems this to be appropriate"[15]

- **Tier 2**: "The distributed infrastructure of the Tier 2 banks facilitates decentralized payments through DLT protocols that allow for simultaneous access, validation and record keeping. In order to do this the Tier 2 banks utilize their computer network and multiple nodes or locations, typically over the Internet."[6]

To foster a technologically neutral environment, the PBOC encourages Tier 2 players to provide innovative e-CNY circulation services and user management procedures, developing innovative payment products, platforms, and business processes. Furthermore, to ensure a level playing field and foster financial inclusion, the PBOC has also developed its own e-CNY app that will provide e-CNY services to all users, including those who do not have an e-CNY digital wallet linked to a bank account.

4.3 The Use of Blockchain for CBDCs

As of today, the e-CNY stands as the sole significant instance of a Central Bank Digital Currency (CBDC) in practical operation. However, several other nations have either initiated trials or embarked on research endeavors toward the development of their own digital currencies. Some of these research initiatives have demonstrated an interest in leveraging blockchain technology. For instance, South Korea has conducted trials involving a digital won on a distributed ledger, utilizing technology from the blockchain division of the local tech behemoth, Kakao. Nevertheless, there is a prevailing

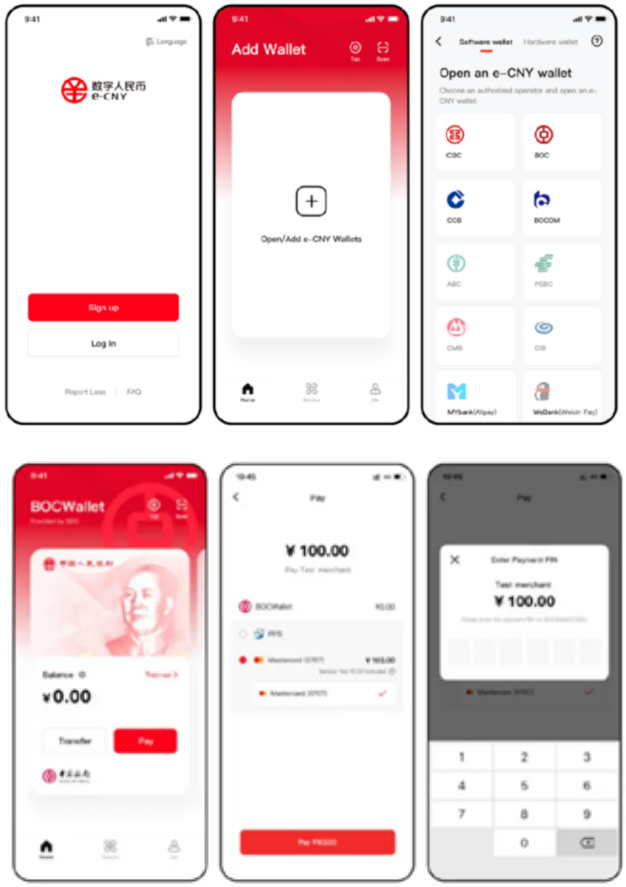

FIGURE 11: e-CNY APP [36]

consensus that blockchain technology is not imperative for the implementation of a CBDC. One notable challenge associated with public distributed ledgers pertains to scalability. Proof-of-work blockchains, such as the one underpinning bitcoin, are renowned for encountering severe bottlenecks in terms of transaction throughput, thus posing a significant obstacle to scalability.

4.4 e-CNY App

In 2014, China introduced the digital Renminbi, also known as the e-CNY, a digital version of the Chinese Yuan. Over the past decade, the project has undergone several stages of development and integration, culminating in its adoption on a global scale in 2024. In fact, China has expanded access to the digital Renminbi application to more than 210 countries and regions. Notably, on March 18, 2024, the People's Bank of China published a user guide to facilitate the use of the app by foreign visitors as well.

Currently, the app offers five main features:

- **Wallet Opening and Management:** Users can easily open and manage their e-CNY wallets through the application by registering and using a phone number from one of the 210 enabled countries and regions, without the need for a bank account, visiting a bank branch, or presenting identification documents. However, in this case, the limit for each transaction will be 2.000 CNY and 5.000 CNY per day. Beyond this, users are free to set parameters such as daily spending limits and link different bank cards.
- **Wallet Reload:** The digital wallet can be reloaded using various options, including payments with international credit cards, local bank cards and even foreign currency bills[36].
- **Peer-to-Peer Payments:** Users can transfer small sums of money from one user to another, allowing virtual currency to be used for non-business transactions as well.

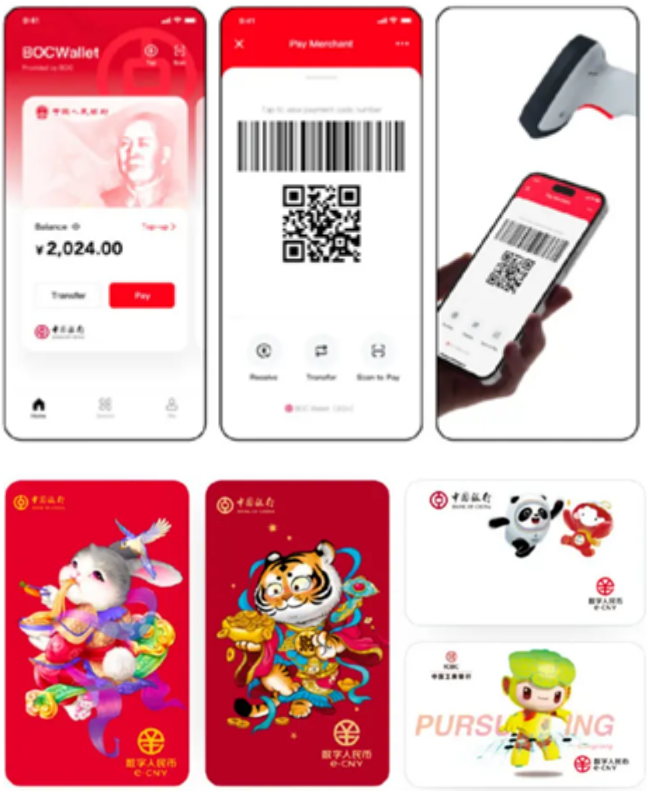

FIGURE 12: e-CNY APP [36]

- **Online and At Merchants Payments:** The e-CNY can be used to pay for goods and services online and at merchants who accept this form of payment, thus offering a wide range of spending options such as "Scan to pay" and "QR Code Payment"[37].
- **With the e-CNY app**, users can request a card or hardware wallet for wearable devices directly from their phones. Simply log in to the app and visit the dedicated section. This new feature allows users to easily connect their cards and hardware wallets to wearable devices for even simpler management. Additionally, with Mobile Pay, available for Android phones, users can make payments even when the phone is off, offering an unparalleled level of convenience. Users can check their device's compatibility by visiting the Hardware Wallet page in the e-CNY app. Furthermore, those who own a super SIM card from China Mobile, China Telecom, or China Unicom can open a SIM card wallet directly from the e-CNY app on their Android phones[38].

Foreign visitors can now register on the e-CNY app using their international phone numbers, streamlining the process of accessing and using e-CNY. A Chinese ID card is required to access advanced wallet options. The wallet, linked to a bank account and equipped with ID card verification, has a single payment limit of 50.000 yuan, a daily cumulative limit of 100.000 yuan and a maximum balance of 500.000 yuan. On the other hand, anonymous transactions can be carried out using the wallet, which has a single payment limit of 2.000 yuan, a daily cumulative limit of 5.000 yuan and a maximum balance limit of 10.000 yuan[18].
China has introduced a new feature for foreigners, allowing them to top up their e-CNY digital wallets before making payments, thereby enhancing their experience with the digital yuan payment system.

4.4.1 Differences between using International Cards Linked to WeChat Pay and Digital RMB (e-CNY) in China

With the growth of payment options in China, foreigners are faced with several options. Among them, linking international cards to WeChat Pay and directly using digital RMB (e-CNY) represent

two practical solutions, but with distinct characteristics.

- **Link international cards to WeChat Pay:** Allows credit or debit cards issued outside China to be linked to WeChat Pay. This option is particularly useful for temporary visitors, although it may be subject to limitations imposed by banks or regions, and incur additional costs for currency conversion.

- **Digital RMB payments (e-CNY):** Allows the user to directly use digital currency issued by the People's Bank of China, eliminating exchange rate issues. This method requires the installation of a digital wallet app and verification of the user's identity, and is applicable to a wide range of payment scenarios.

China's goal is to promote e-CNY as a global payment option, allowing foreign tourists to top up their digital wallets through payments made with Mastercard and Visa cards. This allows them to conduct transactions without having to resort to currency exchange or carry large amounts of cash. In parallel, the intent is also to integrate e-CNY into China's domestic payment system, thus providing a secure and convenient digital solution for Chinese citizens.
The main advantages of the e-CNY app lie in the security ensured through the use of various technologies, such as encryption and digital certificates, the privacy ensured through various levels of anonymity that allow users to make small transactions without having to disclose personal information, and the ease of use, which is inspired by relevant mobile payment platforms such as WeChat Pay and Alipay.

5. Next Steps

China's financial authorities have invested millions in resources to carry out the development projects of the Digital Renminbi (e-CNY) and currently, the results show clear progress even in comparison with the West. Starting in 2019, when the project of a digital currency really began, until now that we are just a few steps away from seeing a large-scale experimental circulation of the e-CNY (e.g., Project Orchid in collaboration with MAS), a series of events have followed one another that have forced us to review and rethink the structure and architecture of the Chinese digital currency several times. The evolution of projects for the distribution of a Chinese digital currency has led to the distinction between a wholesale distributed currency wCBDC and a retail currency used by the rCBDC population. In this scenario, the People's Bank of China is collaborating synergistically with the Monetary Authority of Singapore (MAS). Singapore's financial authority has announced details of new initiatives to expand its financial cooperation with Chinese authorities, including a cross-border pilot program involving retail use of the latter's central bank digital currency (CBDC)[24].

5.1 The Present

Changchun Mu, director of DCI, in the two-day conference of the BIS Innovation Summit 2023 emphasized that:
"We live technological innovation in an era of uncertainty. Together with representatives of the central banks of the United States, Spain and Chile, he spoke on the topic The process of technological innovation in central banks, comparing innovation in the public sector with innovation in the private sector for much of the meeting"[8].
One of the reasons for distinguishing between two types of CBDCs, one retail and the other wholesale as stated during the meeting (BIS) is due to several issues:

- Ledgers (DLTs) are not suitable or for now inefficient to make the process scalable to retail customers, in other words they do not meet the retail requirements for a population as large as China's.

- Linked to the previous point, the problem intensifies when we consider cross-border transactions globally.

- Lack of skills and abilities to manage the processes related to the transmission of payment information.
- The process that combines Offline and Online transactions is not yet well defined;
- The problem of decentralized information. Advanced DLTs are not decentralized because:
  - The management of computer source codes is not self-powered;
  - The organization of network paths;
  - The technological path of the entire DLT gorvernance.
- Another problem is related to the issuance of stablecoins, which are actually issued by centrally managed fintech companies, as well as the associated smart contract as a result.
- Cascading, meaning that all the money flows generated are managed by centralized banks that support a pool of assets governed by algorithms that will be proprietary and therefore subject to risks of transparency and manipulation at multiple levels, starting with prices.
- If everything were decentralized, the problem that would arise later is induced by issues of maintenance and updating of the systems that regulate and incorporate DLTs, and this is not possible automatically. It is necessary to rely on specialized service providers who would provide a centralized service.

Summing up these issues, it all comes down to a discourse of liquidity and market risk for central banks, since all the points mentioned above are connected by the process of decentralization that starts from central banks and is recentralized by financial institutions. According to this approach, some of the supervisory requirements of the supervisory authorities are missing. Central banks, being responsible for the issuance of FIAT currency, its operation and settlement, cannot allow the process to be reduced to centralization to financial institutions. Lacking the requirements that characterize central banks, including that of being a lender of last resort and the PCC to mitigate the risk of default of OTC transactions, the risk is related to trust problems, because DLT is based on Blockchain technology (in the mBridge reference project). The contrast between decentralization and centralized systems emerges when looking at the choice of technology to use to face the global challenge of a multi-CBDC platform and the delicate issue of regulation which must be continuously updated. Central banks must be able to build a regulatory framework with characteristics of flexibility and harmonization between different jurisdictions, capable of simultaneously accommodating technological innovations. The guidelines drawn up by international regulators, various committees and management boards converge towards this type of solution. Alongside this issue Europe has said it is adamant about taking a different position on data protection and privacy through the General Data Protection Regulation (GDPR), while China has stated that one of the purposes of the CBDC is to prevent tax evasion and this means that the authorities will be able to obtain information or data if necessary, therefore it will be appropriate to follow developments also with a view to comparing differences in terms of data and privacy policies that could influence the development of CBDCs.
In other words, the battle for CBDC in the EU [European Union] and the USA [United States of America] is based on privacy in fear of the government comprehensively controlling and understanding the flow of payments. With China's CBDC, the government controls both the processing technology and account holder data, but needs court-issued warrants in case officials want to settle both sides. China has recently introduced data policy laws that are much more stringent than the EU's GDPR and these data laws do not allow the Chinese government to turn to a phone company to investigate an individual, but they need a specific warrant. The Western response of the United States and the Eurozone to this regulatory advancement consists in having created a project for a digital currency model that is able to prevent the government from taking possession of the data and the anonymous storage remaining in the hands of banks or organizations by handing over only the transaction system to governments while maintaining privacy through ledgers.

5.2 mBRIDGE Project

The continuous search for interconnections on every socio-cultural aspect and globalization have also transformed the economic and financial system of payments. Today's system of cross-border payments, particularly for CBDCs, calls for increasingly challenging and innovative requirements for the technologies and infrastructures available. Between 2019 and 2020, the G20 launched a global programme, involving the central banks of many countries, to improve the cross-border payments system called mBRIDGE. The result of the cooperation of several countries in projects, including Jasper-Ubin (Bank of Canada and Monetary Authority of Singapore (2019)), Stella (European Central Bank and Bank of Japan (2019)), Aber (Saudi Central Bank and Central Bank of the United Arab Emirates (2020)), Jura (BISIH et al (2021b)) and Dunbar (BISIH et al (2022)), mBRIDGE is the final result that led to converge towards the realization of a joint project between the BIS Innovation Hub Hong Kong Kong Centre (HKC) and four central banks in Southeast Asia and the Middle East: the Hong Kong Monetary Authority (HKMA), the Bank of Thailand (BOT), the Central Bank of the United Arab Emirates (CBUAE), and the Institute for Digital Currency of the People's Bank of China (PBCDCI).
The main feature of mBRIDGE is the identity of a single platform with direct access with MVP features [4] capable of reflecting cross-border multi-CBDC arrangements imposed by central banks to:

1. Efficiency (24/7);
2. Minimum transaction costs;
3. Real time;
4. Scalability.

And (network of direct central bank and commercial participant connectivity and greatly increase the potential for international trade flows and cross-border business at large.) can provide a direct connectivity network between central banks and trading participants and significantly increase the potential of international trade flows and cross-border activities in general.
The prerogatives of central banks remain those of preserving and integrating:

1. Monetary sovereignty;
2. Monetary and financial stability;
3. Policies;
4. Normative;
5. Privacy.

The systems architecture of the DLT-based platform has been totally replaced by a new private and permissioned blockchain developed specifically in a tailored (or custom) way and called the mBridge ledger (mBL) to meet the requirements listed above of central banks and trading participants. The innovation of this project is given by the extreme level of openness to make contributions to the project. It is possible to freely access codes and implementations through specific APIs that guarantee maximum flexibility towards revisions and innovation. In addition, it should be considered that in the pilot version of the project, participants will be asked to provide feedback and suggestions through structured questionnaires, to improve the platform based on individual experiences.
"The mBL is a specialized, flexible and scalable implementation for multi-currency cross-border payments. To maximize the accessibility, adaptability, and extensibility of the platform for current and future users, the platform implements a modular design that provides users and developers with a familiar service-oriented architecture. In this approach, the different modules such as payments, foreign exchange, capital management, and compliance are decoupled and modularized to meet the

[4] i.e. able to connect entities not belonging to the central bank. A minimum version of a final product that is delivered immediately to the market. It's typically simple, appealing, and bug-free. The MVP is a version of a product that has only the features needed to remain profitable. It only has the basic functionality. Delivering an MVP to the market allows you to get immediate feedback on the value of the product[17].

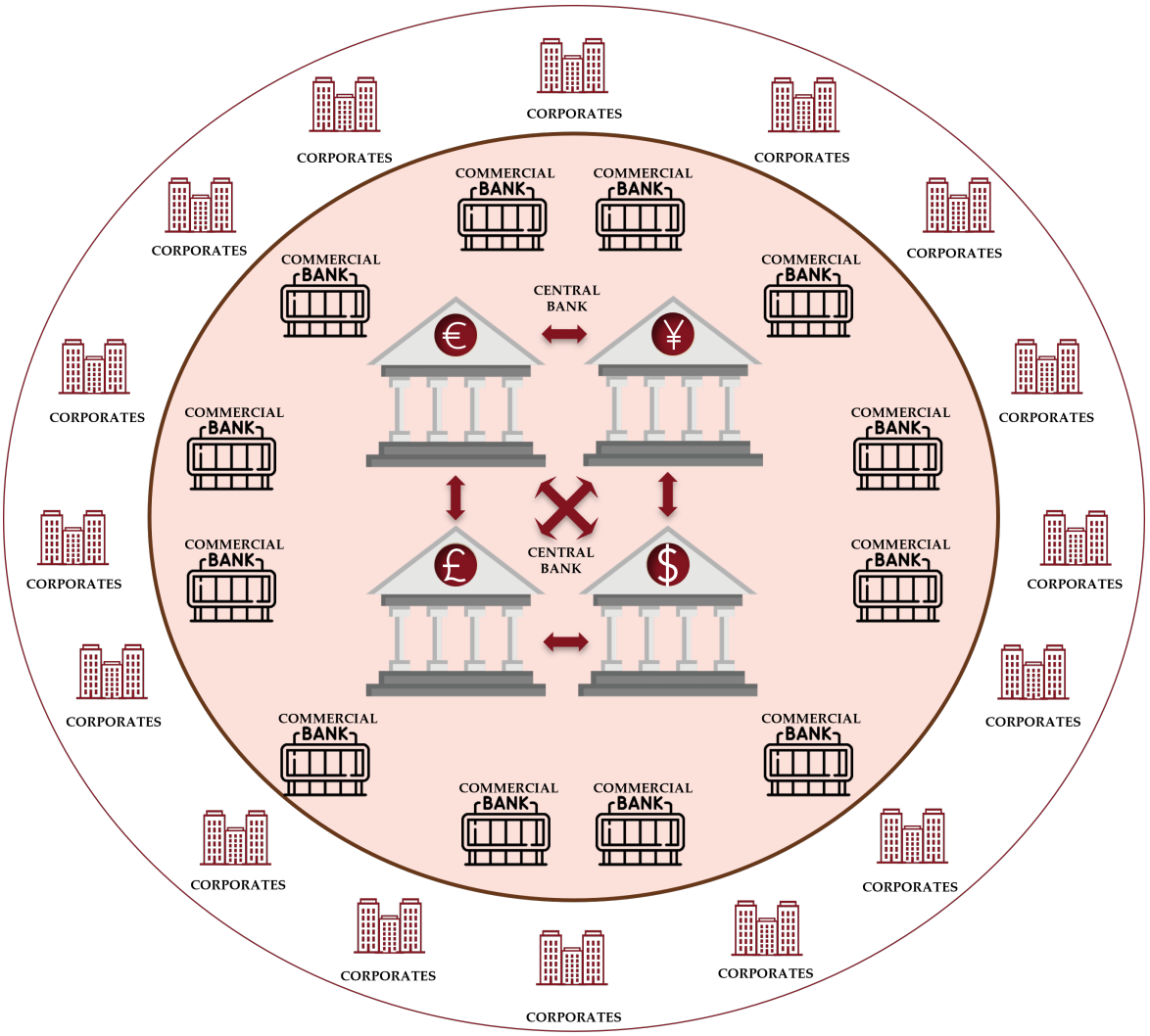

FIGURE 13: mBridge Platform - Network Design

evolving needs of different jurisdictions. This allows participating central banks to validate, adapt and extend functionalities according to their own technical, commercial and regulatory requirements, and aims to support the autonomy of each jurisdiction in the implementation and adoption of the platform"[5].

5.2.1 Features of the Architectural Design

The peculiar features of the architectural design and the mBL Blockchain that govern the platform's functionalities are summarized below.

Network topology
The mBL liaison structure is that central banks are responsible for carrying out validation operations according to the requirements of the protocol consensus. Each of the central banks provides for the inclusion of commercial banks in the same jurisdiction, significantly expanding the interconnection network by offering their customers the opportunity to take advantage of cross-border CBDC services.

Functional architecture
As presented in chapter 3 and chapter 4, we do not review the different functional modules that make up the classic architecture of these types of platforms, so please refer to chapter 3, 4 for more explicit details and we limit ourselves to listing them:

1. Access Level;
2. Application Layer;
3. Data Layer;
4. Blockchain Layer;
5. Basic Service Level.

Consensus Protocol
The mBridge platform is a private and permissioned distributed system, where transaction validation takes place via a central consensus mechanism in DLT platforms. Known consensus mechanisms include proof-of-work and proof-of-stake, but for private and permissioned systems, such as mBridge, there is no need for economic incentives for public validators.
A desirable consensus mechanism must have Byzantine fault tolerance (BFT), i.e., the ability to withstand malfunctioning components that provide conflicting information.
mBridge uses HotStuff+, a variant of HotStuff, which scales linearly with the number of validating nodes, unlike most other BFT protocols that scale quadratically. This allows for greater computational efficiency. Development teams have developed a new dynamic threshold consensus (Dashing) mechanism for permissioned blockchains. Dashing improves efficiency and robustness over HotStuff+ by using triple certificate security, which involves the use of three certificates with different thresholds in different network circumstances. This approach allows for greater efficiency and scalability, especially when there is high transaction concurrency.

Privacy Controls
The design of CBDC platforms must carefully address choices related to privacy, which is not a binary issue between complete anonymity and total disclosure. There are many nuances to consider. For example, in cash transactions, only the parties involved know the existence of the transaction, not the issuer of the currency. However, for transactions of large amounts, such as the transfer of real estate securities, some information about the origin of the funds is often required. The implementation of privacy in mBridge involves the mBridge platform incorporating privacy controls to protect critical transactional data, such as payer and payee identities, the amount, and details of the CBDC. It uses pseudo-anonymous addresses with randomly auto-generated key pairs, ensuring that only the parties involved and their respective central banks can see sensitive transaction details. As example: "In a hypothetical transaction scenario, if a UAE bank makes a payment to a Hong Kong bank in e-HKD on mBridge, the transaction details would only be visible to clearing members and their central banks. Other participants, such as the Bank of Thailand (BOT) and the People's Bank of China (PBCDCI), would not see the details. If the payment was in e-THB, the BOT would also see the details." The need for Privacy Controls is determined by the fact that without these controls, every participant in the mBridge platform could access sensitive transaction details, as all information would be visible on the shared ledger.

Functional Implementations

1. Issuance and redemption. It is planned to define a system that provides for automated or manual integration, capable of also connecting with traditional payment systems, especially with reference to countries or jurisdictions that have not yet adopted a CBDC system or that in any case do not have the provision of integrated APIs:
   (a) Manual Issues and Refunds;
   (b) Automatic Issues and Refunds.
2. Payment and PvP are critically tought divided into two categories:
   (a) Simple, single-currency push payments;
   (b) Dual-currency PvP FX transaction.

5.2.2 Political Considerations

The creation of a common multi-CBDC platform involves various political, legal, and regulatory considerations, given the differences between the monetary and governance systems of the four jurisdictions involved. This made it possible to explore a flexible design that respects the specificities of each jurisdiction, while maintaining common principles that are fundamental to the operation of the platform.

Measures to Preserve Monetary Sovereignty
A crucial issue concerns the protection of central banks' monetary sovereignty, as cross-border access to CBDCs could destabilize national monetary systems, leading to volatile capital flows and currency substitution. To mitigate these risks, the platform must consider whether to allow commercial banks to access CBDCs from other jurisdictions.

mBridge Platform Project
The mBridge project allows both domestic and foreign banks to hold and operate in CBDCs, facilitating cross-border payments without hampering public policy or central bank capabilities. The platform provides flexible controls on the issuance, redemption, and use of CBDCs to ensure that each jurisdiction's monetary sovereignty is respected, allowing for customization according to local needs.

Pilot Operations
During the mBridge pilot, participating banks were allowed to operate in CBDCs from other jurisdictions, but foreign banks had limitations on the movement of CBDCs. The transactions excluded domestic and cross-border transactions in foreign currencies to ensure that a national bank was always involved, avoiding the accumulation of offshore domestic currency and limiting speculative use. Additional analysis and countermeasures will be required before excluding transactions can be included in future phases.

Data Privacy and Governance
Data privacy and governance are critical to mBridge's success, considering the involvement of several central and commercial banks. During the pilot, sensitive data was stored off-chain and shared only on a necessary basis, protecting users' identities through pseudo-anonymity. However, the pilot's centralization has raised privacy concerns. In the future, a decentralized distribution of data will be explored, where only a few pieces of data are recorded on the blockchain, while sensitive data remains in local, encrypted databases.

Legal and Regulatory Considerations
Legal Categorization of CBDCs can be classified differently (such as currency, representation of funds, debt, etc.) depending on local laws, requiring possible regulatory updates.

Central Banks' Participation
The powers of central banks, focused on the stability and integrity of financial systems, support their participation in mBridge. Regulatory adaptations may be necessary to ensure compliance.

Role of the Platform Operator
The management of the platform can be decentralized, with each participating central bank responsible for specific governance roles. Some core tasks may require a dedicated structure.

AML/CTF/Sanctions Compliance
Participating commercial banks must comply with anti-money laundering, anti-terrorism, and sanctions regulations, with the platform certifying transaction compliance.

Purpose of the Regulation
The settlement of transactions was achieved through legal agreements between central banks and commercial banks, adapted to local regulations.

Privacy Laws
mBridge's pseudo-anonymity and privacy protection features must be adapted to different local data privacy and governance regulations.

Other Legal Considerations
Further analysis of laws regarding contracts, intellectual property, competition, cybersecurity, and dispute resolution is needed for a production-ready system.

Trying the conclusions, while central bank participation in mBridge is generally possible, regulatory adjustments and a robust contractual architecture may be required to ensure legal certainty and regulatory compliance.
On June 5, 2024, a press release by BIS, related to the mBRIDGE project was published. It is stated that a great result has been achieved: the achievement of the minimum viable product stage. Reaching this important stage determines a crucial point since implicitly all the functional requirements to proceed with the extension of the project on a large scale are present. In addition, with a view to collaboration, the works were opened to international participants in order to create synergy.

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