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Central Bank Digital Currency (CBDC) analysis with case study on E-CNY pilot circulation

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Summary

Abstract

This thesis delves into the realm of Central Bank Digital Currencies (CBDCs), with a specific focus on the Chinese CBDC, the E-CNY. The study primarily aims to provide an analytical review, combining both quantitative and qualitative data to assess if and how the pilot aligns with the theoretical objectives of a retail CBDC and the specific goals set by Chinese authorities.

The research begins with an introductory analysis of CBDCs, exploring potential impacts on stakeholders, including advantages, drawbacks, and the associated monetary policy and financial risk. A case study on E-CNY to follow, examining its theoretical purposes and practical implementation. The final chapter offers a detailed investigation of the first Chinese E-CNY pilot, tracing its evolution from 2021 to mid-2024. Research is conducted through in-depth analysis of cities' Official Websites for publications and reports, either on quantities or on coverage and policies.

Findings reveal that the vision for retail E-CNY as a mainstream retail payment solution is a velleity at present. Is really difficult to root out habitudes and the resolution balance Alipay and WeChat duopoly is far from being reached. Strategies diverge between incentives for daily retail consumption and solutions for SME and Corporations. Some cities are exploring innovative applications of E-CNY that if successful could be expanded nationally or internationally.

Government should prioritize educational and awareness campaigns, implement tailored regulations for E-CNY as well as transparent rules on collection and sharing of personal information. Additionally, it needs to develop mid- to long- term strategies attract and retain users, rather than relying on short-term promotions and discounts that result in wallet openings without sustained engagement. Time and endeavor are the answer of a project that is still on its first wide steps.

Introduction

Before the pandemic CDBCs would be considered on a par with cryptocurrencies. At present, 130 Countries, representing 98% of global GDP are exploring a CBDC. 19 of the 20 G20 countries are in the advanced stage of CBDC development.[1] Nigeria, Bahamas and Jamaica have already launched their CBDC. China paves the way as the first superpower at phase 3 pilot of its E-CNY which is currently available for retail circulation in numerous selected provinces.

The dynamics leading to a multipolar creation of CBDC are found in decreasing use of cash, an aspiration for financial inclusiveness and digital payment innovation, a response to cryptocurrencies market as well as companies' private currencies, a solution to keep the pace with rushing COVID and post-covid digitalization, nonetheless the competition between countries to be the first, therefore the better prepared ones if CBDCs will become an international reality.

The first chapter will serve as an in-depth introduction to the newborn, wide and constantly evolving realm of CBDCs. A wide definition is provided, followed by the foundational principles and core features that would constitute a CBDC. Later on, an analysis of CBDC taxonomy, with retail and wholesale CBDC partition. For the purpose of this thesis, the subsequent focus will be aimed at retail CBDC, even though probably the two will eventually interrelated. Consequently, a breakdown of the design, architecture and infrastructure choices a CBDC may be established on. These will be intrinsically embedded to the technology platform and the type of ledger adopted to fulfill and account payments. However, these two will be elucidated only to shed light on the design choices, because there would be the risk to go offtrack from the main topic analysis and over my field of competency.

Great importance is attached to the legal framework that would legitimize a CBDC activity, followed by an analysis of privacy implications, which result one of the major concerns to the general public, the destined consumer in a retail CBDC framework. Ultimately a survey on the retail CBDC stakeholders will be carried, investigating risks and opportunities that a CBDC will bring forth.

The second chapter presents a case study on the Chinese E-CNY pilot, following the same structure as in the first one for a detailed analysis. It examines the taxonomy, design,

[1] https://www.atlanticcouncil.org/cbdctracker/

architecture, infrastructure, technology, legal framework, privacy concerns, and stakeholders mirroring the path traced in the first chapter. The objective is primarily to comprehend if and how E-CNY complies with CBDCs general theoretical framework. Secondly, to explore the underlying reasons, the objectives and visions behind this pioneering pilot, together with the likelihood of its broad take-up in an already massively digitalized payment ecosystem.

The last chapter of this thesis analyzes the E-CNY pilot. First, an overview and comment of national data, pertaining Wallets Opened, Number of Transactions and Transaction Volume, accompanied by Average Spent per Transaction, Average Spent per Wallet and Average Transactions per Wallet.

Second, an analysis of the "10+1" pilot, i.e. an investigation of the nine cities - Shenzhen, Suzhou, Xiong'an, Chengdu, Xi'an, Qingdao, Dalian, Shanghai and Changsha-, one province – Hainan - and the 2022 Beijing Winter Olympics, the "+1" of the pilot. "10+1" is the name bestowed by the Government to the pilot. The nine cities and Hainan province were the first to implement E-CNY payment system. Reasons can be found in economic and territorial distribution as well as technological inclination. Wallets Opened, Number of Transactions and Transaction Volume are analyzed and compared to the total Resident Population and the city's GDP. In addition, as per the national data, Average Spent per Wallet, Average Spent per Transaction and Average Transactions per Wallet are calculated whenever possible. Quantitative analysis is integrated with qualitative one, investigating on each city's Coverage, Policies and Activities. An in-depth comment for each city will elucidate on the results of the research, make a comparison with national data and other cities' ones, with a final glance addressing whether strategy adopted for each city is effective or not.

The purpose of this thesis is to elucidate on a futuristic topic, that is rapidly becoming a reality without the general public understanding its most basic features. China is in the forefront, both for the retail pilot and for cross-border wholesale multicurrency projects. The ultimate result will rely on the actual governmental resolution to sustain this type of money and its circulation, in an attempt to provide an alternative mean of payment beside and alongside WeChat and Alipay, to both rebalance their duopoly and be the first, best developed international CBDC.

前言

本论文探讨了中央银行数字货币（CBDC），特别是中国的 CBDC——数字人民币（E-CNY）。我将解释 CBDC 的所有理论和具体特征，尤其是 E-CNY 的特性，并对 2020 年中国的“10+1“数字人民币试点进行分析。研究内容分为三章，接下来我将进行简要概述。最后，我将提供研究结果的简短说明。

第一章详细阐述了 CBDC。首先提供了一个定义：CBDC 是由国家中央银行发行一种货币形式，因此它是中央银行的直接负债，不与任何商品挂钩。CBDC 分为两类：零售型 CBDC 和批发型 CBDC。在本论文中，仅研究零售型 CBDC。零售型 CBDC 旨在为消费者的日常零售消费、个人间的转账和企业间的交易工具。零售型 CBDC 进行实现快速、免费且安全的数字支付。它还旨在促进没有银行账户的人的金融包含性，以及在危机或自然灾害发生时让政府直接向人们发放补贴，因为零售 CBDC 理论上不需要互联网来支付。

因此，作者详细解释了 CBDC 的设计、架构和基础设施特征。文中讨论了平台是基于匿名化的代币转移还是基于身份的账户体系。基础设施包括 CBDC 的操作体系。操作体系可能是单层运营，即中央银行直接发行与分配 CBDC 和处理付款，或者是双层运营，即中央银行发行货币后通过金融机构、商业银行和支付服务提供商（PSP）进行分配与处理付款。基础设施的选择取决于体系所依赖的账本类型，可以是集中式账本或分布式账本。许多 CBDC 试点基于分布账本技术（DLT），而区块链本身也是建立在这种技术之上的。随后，章节继续探讨 CBDC 法律框架和隐私问题。首先，法律框架旨在是否存在发行 CBDC 法律权威、是否仅由中央银行享有铸币权、以及该 CBDC 是否具备法偿性。隐私问题则源于对政府大规模监控、过度数据收集与共享的担忧，并且个人数据可能被窃取的网络安全风险。第一章的最后部分分析了参与 CBDC 发行、流通与管理的利益相关者，主要包括中央银行、政府、商业银行、终端用户、技术和支付服务提供商以及国际组织。我列举了每个利益相关者在 CBDC 方面可能面临的利弊、机会和风险。

第二章与第一章的结构完全相同，但内容是基于数字人民币（E-CNY）。数字人民币是由中国人民银行发行的零售型 CBDC，未来可能还会发展为批发型 CBDC。其采用双层运营，即由中国人民银行发行数字人民币、而由指定运营机构负责系统的分发

和管理。运营机构包括中国的银行与电信公司。数字人民币应用数字人民币 APP，用户可以通过该平台进行交易。平台上的数字钱包取决于客户个人信息识别的强度（四类数字钱包是匿名的，仅需手机号即可办理）、还有个人钱包和对公钱包、软钱包和硬钱包最终有母钱包和子钱包。每个人或公司可以通过不同的指定运营机构创建多个钱包。关于技术，数字人民币基于分布式账本技术（DLT）与部分集中的特性相结合，但具体细节保密，以确保系统的安全性。

法律框架和隐私问题借助相关法规进行分析。数字人民币拥有法偿性，但文献中存在一些批评。同时，隐私问题则通过对法律与数字人民币 APP 上的个人信息保护政策的分析进行探讨。最终利益相关者来分析，深入研究了中国的具体情况，例如通过数字人民币实现人民币国际化的可能性、数字人民币与微信支付和支付宝它们关系的未来，以及中外消费者可能做出的反应。

最后一章进一步对数字人民币进行了研究。研究过程中遇到的一个问题是数据缺乏或未公开，因此关于开立钱包数量、交易数次和交易金额的数据表格大多不完整。对于已有的数据，我计算了每个钱包的平均消费金额、每笔交易的平均消费金额与每个钱包的平均交易次数。我还将全国数据与“10+1”试点城市的数据进行了对此，该试点于 2020 年启动，并分析至今。

结果显示，尽管有各种推广措施，但是数字人民币距离成为人民银行所渴望的日常消费工具。首先，交易金额的分布集中在苏州市。苏州市一地就占了宗交易额 6.6 万亿人民币的 75%。

其次，钱包的平均交易次数表明，很多钱包在开立后使用频率较低或未被使用。每个钱包的平均消费金额和每笔交易的平均消费金额显示中高金额交易的趋势，而非小额消费。这进一步证明了数字人民币目前更适用于偶尔消费，而不是日常消费工具。

最后，政策与活动的策略主要向高频消费和企业。企业相关的政策是到此为止最为成功的政策。微型企业、中小企业和大型公司受益各种贷款、补贴和为企业提供便捷税收支付服务。值得注意的是关于贷款和补贴政策，此政策频繁地针对支持乡村振兴与数字化。

从这些数据和结果来看，当前数字人民币主要是一个为企业提供融资和推动数字化地平台。虽然中国人民银行愿望数字人民币成为像微信支付和支付宝一样的小额支付和高频交易平台从而成为日常地消费工具，但目前政策更成功地促进了高金额消费。

人民银行需要调整策略，增加用户的留存率，推行中长期促销措施，如订订阅服务、尽可能扩大覆盖范围、更有效地提升用户对产品便利性的认知、制定专门的数字人民币相关法律、并对数据收集与共享保持透明。这些可能提高消费者的信任，逐步提高用户对平台的参与度，或许可以先从小利基或行业入手，逐步扩展到日常消费领域。

Chapter One - CBDCs

The aim of this first -introductory- chapter is to understand thoroughly what is a CBDC. In doing so I decided to structure the chapter as follows: a definition of CBDC, what kinds exist, design choices, architecture and infrastructure; legal framework and privacy concerns to observe law and regulation that may back it. Lastly who are the stakeholders in the projects, what are the advantages and disadvantages for them in issuing such a money what are the possible effects in the monetary financial and banking system.

1.1 A definition

A CBDC – Central Bank Digital Currency - is a digital payment instrument and a digital form of currency issued by a Country's central bank, therefore is a direct liability of the central bank. CBDC is a fiat currency, i.e. is not linked to a commodity (unlike cryptocurrencies' stablecoins) and are backed and operated by the State Central Bank that generated it. CBDC are considered a digital version of cash, i.e. not to be intended as a traditional reserve or settlement account but more as a digital wallet, such the already existing ones such PayPal, Satispay, Alipay and WeChat Pay as the most used. As the Committee in Payments and Market Infrastructures jointly with the Market Committee (CPMI-MC) stated in 2018, commercial banks and private institutions already have access to digital form of Central Bank money, the innovation resides for the general-purpose users, which can currently access to the public money only through cash.[2]

A CBDC will be seen as a way to let people have access to public money, at the same time it must be conceived as a ready omni-present mean of payment. As just stated, can be considered a digital form of cash so it's potentially accepted everywhere within the country or region borders. Moreover, it may be use for online purchases, retail in person purchases and exchanges without an internet connection. CBDCs surpass the limit of cash: they would

[2]https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-central-bank-digital-currency-cbdc; Committee on Payments and Market Infrastructures (CPMI) and Markets Committee (MC), *Central bank digital currencies*. Bank of International Settlements, No 174, 2018.

enhance privacy, limiting at the same time illegal activities, they would ease fiscal transfers and be a form of "programmable money".[3]

BIS stated that CBDC foundational principles should:

1) Do no harm to the central bank public policy objectives and financial stability;

2) Coexist with cash, will complement public and private forms of money and means of payment;

3) Promote broader innovation and efficiency. Whereas the role of the public and the private sectors for creating an accessible, safe and efficient payment service system, agents should be free to choose how to carry on their transactions.[4]

BIS and participating central banks also stated the key features of a potential future CBDC system:

- *Instrument features:*
  1) *Convertible: CBDC should exchange at a par with cash and private money;*
  2) *Convenient: CBDC payments should be as easy as using cash.*
  3) *Accepted and available: CBDC should be usable in many of the same types of transactions as cash, including POS and P2P. Possibility to make offline payments.*
  4) *Low cost: CBDC payments should be very low or no cost for the end users.*
- *System features:*
  1) *Secure: The CBDC system should be secure from cyber-attack and other threats such as counterfeiting*
  2) *Instant: or semi-instant finality of settlement of transactions*
  3) *Resilient: to operational failure or disruption*
  4) *Available: 24/7/365 for use by end user, both for the envisioned tokenized or account CBDC designs that will be further explained.*

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[3] Programmable money definition: Programmable money is defined as a unified digital money system that integrates both the storage of digital value and the capability to specify automated behaviors through a computer program. The difference with traditional technologies is that these use a database and external programs connected through an API to combine their functions, being therefore separated. This can lead to outages and too much reliance to external services. https://www.federalreserve.gov/econres/notes/feds-notes/what-is-programmable-money-20210623.html; Bank of International Settlements (BIS), *Central bank digital currencies: foundational principles and core features*, Report No 1 in a series of collaborations from a group of central banks, 2020, Hereinafter referred as "Foundational principles".

[4] *Id.* p.10.

5) *Throughput: ability to process a very high number of transactions per second*
6) *Scalable: system should be able to expand to process potentially much larger additional volumes in the future.*
7) *Interoperable: The system should offer sufficient interaction mechanisms with private sector digital payment systems and arrangements to allow easy flow of funds between systems.*
8) *Flexible and adaptable: to changing conditions and policy imperatives.*

- *Institutional features:*
  1) *Clear and robust legal framework: the central bank should have clear authority underpinning its issuance of a CBDC*
  2) *Standards: The CBDC system and participating entities should conform to the appropriate regulatory standards.*[5]

1.2 CBDCs Taxonomy

There are two types of CBDC: retail and wholesale. Retail CBDC is intended for everyday transaction between private citizens and businesses, in the intended P2P, B2B and B2C way. Wholesale CBDC is conceived for transactions between central banks and financial institutions, both within and cross-border.

A state of play graph herein shows the overall intentions of the 109 Countries with active CBDC projects.

As we can see the majority of CBDC are structured for the retail payments or both retail and wholesale settlement. Only 7,8% of the total projects is for wholesale only. 41% however still don't know what turn take regarding the kind of issuance, due to the fact these countries are still in early stages of the project.

[5] *Id. pp. 8-11*; Soderberg, G., Kiff, J., et al., *How Should Central Banks Explore Central Bank Digital Currency? A Dynamic Decision-Making Framework*. FINTECH NOTE/2023/008, IMF, 2023.

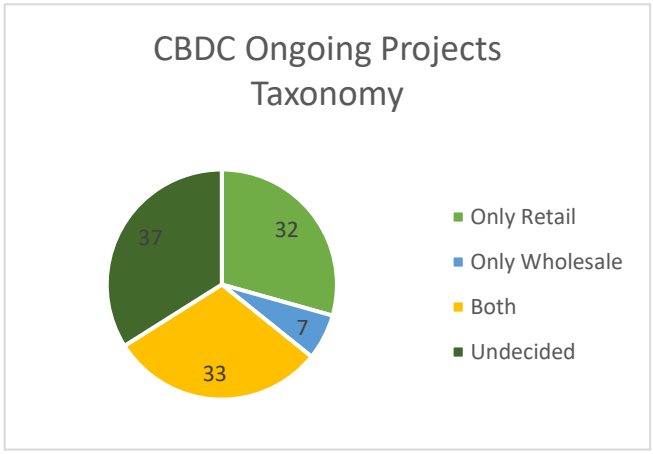
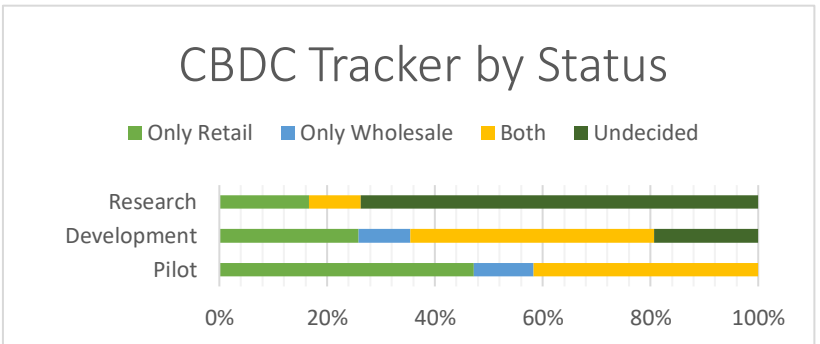


Figure 1 CBDC Ongoing Projects Taxonomy Source: Atlantic Council CBDC Tracker https://www.atlanticcouncil.org/cbdctracker/ Author's elaboration



	Pilot	Development	Research
Only Retail	17	8	7
Only Wholesale	4	3	0
Both	15	14	4
Undecided	0	6	31

Figure 2 CBDC Tracker by Status Source: Atlantic Council CBDC Tracker. Author's elaboration

1.2.1 General Purpose or Retail CBDC

The share of cash payments, whereas may increase in number of transactions, is constantly -even if yet not globally- reducing in volume.[6] A general purpose or retail CBDC would provide a central bank instrument for everyday transactions by households and firms. It differs from the current digital payment instruments as it represents a direct claim on a central bank rather than the liability of a private financial institution. Most of the central banks (CBs) foresee a retail CBDC complementary to an FPS system.[7] The two main differences between these lies in the fact that CBDC involves only CB money, will be available offline and for additional financial and/or institutional services. CBDC will coexist with the current payment system methods, since these last ones are already well developed, trusted and fast means of payment.[8]

[6] https://www.statista.com/statistics/786680/share-of-cash-transactions-at-pos-in-europe-bycountry/#statisticContainer; 69) Khiaonarong, T., & Humprey, D., Measurement and use of cash by half the world's population. IMF Working Paper 23/62, 2023; https://www.bbc.com/news/business-66796263.

[7] FPS: Fast Retail Payment is a payment infrastructure that allows payments between account holders of different PSP (payment service provider) in real or near real time on a 24/7 basis. https://www.bis.org/publ/qtrpdf/r_qt2003x.htm.

[8] Kosse, A., Mattei, I., *Making headway – Results of the 2022 BIS survey on central bank digital currencies and crypto*, BIS Papers No 136, 2023, pp. 10-17; CPMI-MC (2018) Op. cit.

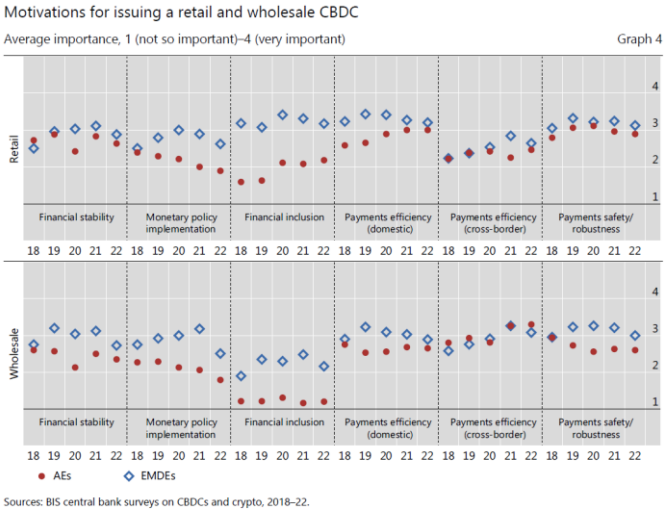


Table 1 on Motivations for issuing a retail and wholesale CBDC. Source Kosse, A., Mattei, I., Gaining momentum – Results of the 2021 BIS survey on central bank digital currencies BIS Paper 125, 2022

Table 1. from BIS paper n.125, shows that the driving force behind the issuance of a retail CBDC alters through time and differs between advanced economies (AEs) and emerging markets and developing economies (EMDEs). These motivations will be analyzed more profoundly in the paragraphs with regards to the Central Banks as stakeholders for what concerns retail CBDC, main focus of this research. Just to outline, main motivations reside in more financial inclusion and payment safety for CB in AEs, while monetary policy implementation and cross-border payment efficiency is not considered relevant. On the contrary for EMDEs' CB financial inclusion is least important, together with monetary policy implementation. Carrying less interest in general, their main driver lays in domestic payments efficiency and more payment safety.

Auer et al. (2021) sustain that central banks paves for retail CBDC more often when there's more IOT and digitalization amongst people. The research also states that retail CBDC projects are more advanced where there's higher innovation capacity and larger informal economy, coherent with governments aim to better track and grasp transaction flows.[9] The decision of issuing a CBDC token would also have the meaning to limit the potential of other digital tokens such as cryptocurrencies. Consumers could face credit and liquidity risks, volatility risk and lack of consumer protection (CPMI-MC 2018).

1.2.2. Wholesale CBDC

A wholesale CBDC is meant for transactions between banks, central banks and financial institutions. The reasons to issue this type of CBDC as we can see in the BIS graphs shown above, AEs are to foster efficiency in domestic payments, cross-border payments and payment safety while in the last year monetary policy implementation dropped as least motivation together with financial inclusion. For EMDEs efficiency in domestic and cross-border payments are the leading motives, ignoring them as a mean for financial inclusion and

[9]Auer, R., Cornelli, G., Frost, J., *Rise of the central bank digital currencies: drivers, approaches and technologies*, BIS Working Papers No 880, 2020.

monetary policies. A multi-CBDC platform, as envisioned by BIS with its multiple projects, would cut the long transaction chains, enhance the disintermediation.[10]

Auer et al. paper correlates wholesale CBDC with financial development i.e. in project to ameliorate efficiency in wholesale cross-border settlements, with a broader vision for further enlarged trade openness.[11]

CPMI-MC states that it would improve efficiency and risk management in settlements; could help reduce counterparty credit and liquidity risks in the financial system. It could also help central banks monitor financial activity.

G20 countries see the enhancement of cross-border payments a priority and identifies CBDC as a potential tool for transactions to, from and potentially within another currency area. This would need a system that won't interfere with foreign monetary policy, financial stability. Ferrari et al., emphasizes the risks of a foreign CBDC holding, i.e. the risk involved in volatility in exchange rates, "digital dollarization" in other nations, or even issues like tax evasion if regulatory frameworks are not aligned.[12]

This system would be engineered to work along with other countries CBDCs for cross border and cross currency transactions. This will require a common, or at least standardized judicial CBDC operability (like an ISO 20022[13] for CBDCs), technical and operational alignments, synchronized operating hours. In a word the aforementioned *interoperability*. For CBDCs to be effectively integrate into this complex landscape, they must complement existing systems and ensure smooth coexistence.[14]

1.3 Architecture, Infrastructure, Access Verification

[10] Kosse, A., Mattei, I., (2023) Op. Cit., p.10.

[11] Auer, R., Cornelli, G., Frost, J (2020) Op. Cit..

[12] BIS (2020) "Foundational Principles"; Ferrari, M., Mehl, A., & Stracca, L., *Central bank digital currency in an open economy* ECB Working Paper Series No 2488/2020, 2020.

[13] ISO 20022: ISO stands for International Organization for Standardization. ISO 20022 is a global standard for financial information providing during interchanges between financial institutions for payments, securities trading and settlements information. https://www.iso20022.org/about-iso-20022

[14] BIS (2020) "Foundational Principles" Op. Cit., p.7.

Henceforth, the focus will be on retail CBDC. Of the multiple projects carried on, different are the CBDCs design choices, i.e. the purposes they may serve. Departing from that there's the architecture, which is the blueprint of the structure, its conceptual framework; infrastructure, is actual technical and technological building in which it would work, are adopted. As stated in the Introduction, only the architecture is widely investigated, while the infrastructure and the DLT technology will be defined only to ensure clarity in the overall explanation.

Notably, the literature is not uniform regarding what to consider fundamental as a design choice. BIS papers I consulted, as well as Arthur and Böhme, CPMI-2018 and M. Khan, consider as fundamental trait for CBDC distinction whether it is account-based or a token based CBDC, i.e. if the system works through identity verification of both parties involved in the transaction or through the validity of the payment, the authenticity of the coin. Other authors such as Jiang - which will be consulted for the privacy concerns - and Garrat this is not relevant for computer architecture distinction, being a CBDC both account based and token based at the same time, viewing instead the operational system, also called the architecture as the real foundation.[15]

Therefore, CBDC taxonomy analysis will further be investigated on this distinction: architecture, infrastructure and access verification, as an organic aggregating form of literature comprehension and interpretation.

1.3.1 Architecture

Architecture and operational system can be considered as synonyms. CBDC architecture could be organized in Direct CBDC, Indirect CBDC, Hybrid and Synthetic. Each one of these could be either account- or token-based, and present different infrastructures.

a) Direct CBDC:

   In this model payment system operated by the central bank, CBDC is therefore a direct claim on the central bank which also keeps all the records and update the accounts. Centralized ledger and payment executor. Is also called one-tier operation model, in which using an account-based model, the CB directly issue,

[15] Garratt, R., et al., *Token- or Account-Based? A Digital Currency Can Be Both*, Liberty Street Economics, Federal Reserve Bank of New York, 2020; Jiang, J., *Privacy Implications of Central Bank Digital Currency*, Seton Hall Law Review, 54, 69-102, 2023.

distributes, and provide CBDC banking services to the end users, as well as the KYC, AML/CFT monitoring, transactions clearing and settling. CB would therefore be responsible to build and manage an efficient technologic infrastructure on a large scale. These services go far beyond its current operations, hence private sector intermediation is often favorably considered by CB. This is the example of the account-based model implemented in the Eastern Caribbean which involves consumers holding deposit accounts directly with the central bank

b) Indirect or Synthetic CBDC:

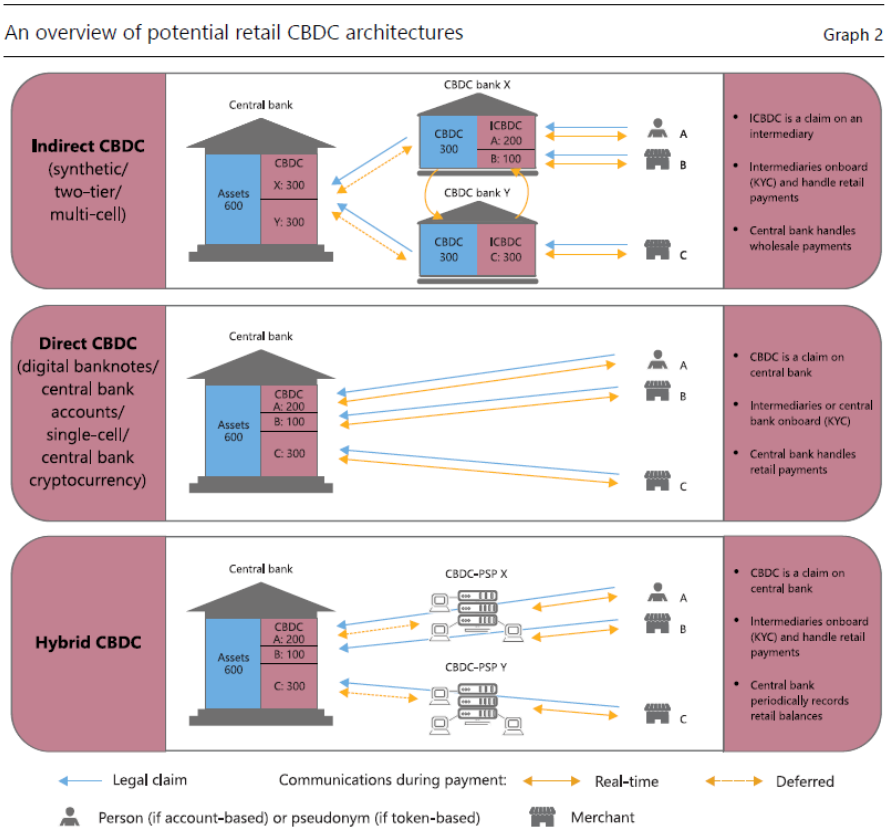


Figure 3 Source: Auer R., Böhme R., The technology of retail Central Bank Digital Currency, BIS Quarterly Review, March 2020, Graph 2.

Here payments system is operated by intermediaries that resemble narrow payment banks; for the consumer the claim is on the intermediary, which handle all the payments and who has the actual claim on the central bank. On the other side central banks only keep track for the wholesale accounts. (Higher-income countries are more likely to issue direct or hybrid structures.) [16] Also named two-tier operation model, the central bank will issue the money to intermediaries such as commercial banks and payment services providers, delegating all the payment services, monitoring, clearing, settling to them, comprised dispute resolution, KYC service and AML/CFT monitoring. The central bank will not possess any information pertaining the parties/consumers.

c) Hybrid CBDC:

[16] Garratt, R., et al. (2020) *Id.*; Kosse, A., Mattei, I., (2023) Op. Cit., p.10.

Is an intermediate solution in which CBDC is still a direct claim on CB, while intermediaries handle requirements, payments and ledger. Central Bank may possess a ledger in the core of the technical infrastructure in case of intermediaries' failure. Legal framework characterizing these CBDCs, grant segregation of the currency from balance sheets of the PSPs (Payment service providers). This means that *de facto* the currency is not an asset of the PSP but a liability of the CB. Insofar, in case of PSP financial difficulties, CBDC holdings can be transferred to another PSP, ensuring portability without disruption. The CB would be entitled to manage this transfer, and in order to do so must hold a copy of all retail CBDC holdings. This solution will burden the CB duties but not as much as the direct CBDC architecture, indeed could focus only in some core processes, while the intermediaries handle all the other services. For instance, China's CBDC pilot relies on private-sector banks to distribute and maintain eCNY (digital yuan) accounts for their customers, but we will extensively discuss it in the second chapter.[17]

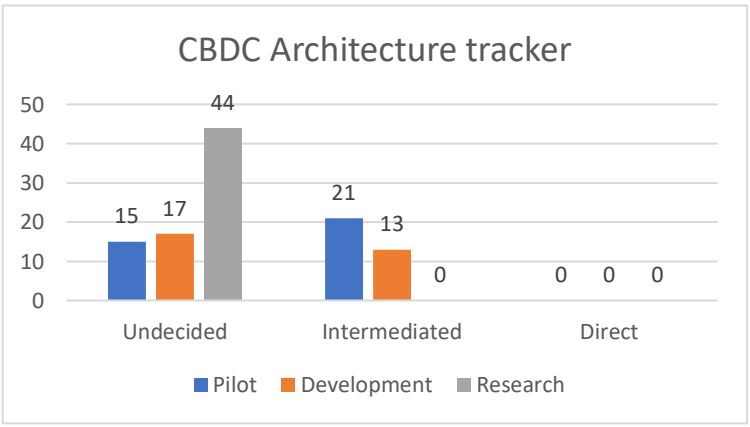


Figure 4 CBDC Architecture choice. Of 112 total active pilot the choice is either yet to be taken or toward indirect CBDC. Source: Atlantic Council CBDC tracker. Author's elaboration.

Looking at the tracker, from a total of 109 active projects, one third is still uncertain to which architecture adopt. No country is on the track to pursue a Direct CBDC. In particular, only Senegal adopted for its eCFA pilot. The BCEAO (La Banque Centrale des États de l'Afrique de l'Ouest) never considered it as a legal tender and criticized it as not compliant to e-money regulations. The project was abandoned in 2016. All 3 launched CBDCs Jamaica, Bahamas and Nigeria have all adopted an intermediated architecture.[18] Bahamas with its Sand Dollar originally paved the way with a direct architecture, now transitioning to an intermediated one. Iceland, Denmark and Norway originally also proposed a direct architecture. Norway is now at the fifth phase of its development stage,

[17] Auer, R., Böhme, R., *The technology of retail central bank digital currency*, BIS Quarterly Review, 2020; Jiang J. (2023; Leucci, S., Attoresi, M., Lareo, X., *TechDispatch on central bank digital currency*, European Data Protection Supervisor (EDPS), 2022.

[18] Atlantic Council CBDC tracker.

testing its E-krone as wholesale CBDC, however with financial institution intermediation. Denmark don't have at present active CBDC pilots, as it doesn't see a use-case for CBDC, at least for now. Iceland also doesn't have an active pilot as it doesn't foresee a Rafkróna, but willing to discuss with the stakeholders' advantages and disadvantages. However, in 2019 the Financial Supervisory Authority of Iceland (FME) approved Monerium's e-money[19] license to create stablecoins using Ethereum blockchain.[20]

1.3.2 Infrastructure

Each one of the CBDC architecture system requires technological complexity. The indirect one is similar to today's ecosystem. The direct one would require a massive technological improvement by CBs, responsible of all those duties otherwise delegated to the intermediaries. The hybrid one would result more complex than the indirect system, because CB would account for the retail balances, however simpler than the direct system. The infrastructure hence regards what kind of ledger should be adopted, if central or distributed, with all the subsequent tradeoffs.[21]

BIS states that in a CBDC payment the transaction is a transfer of a central bank liability, recorded on a ledger. To design this ledger there are 5 key factors: 1) structure; 2) payment authentication; 3) functionality; 4) access; 5) governance.

1) Structure:

A structure could be centralized, decentralized or a combination. A centralized ledger would require an intermediary to manage transfers and liabilities, making easier to carry on the AML features. A decentralized ledger would, on the other hand, ease the peer-to-peer process and offline payments. A hybrid one would have the characteristics of both, like a central storage of the total CBDC issued and individual

[19] Monerium is a financial technology company that is licensed to issue digital money on blockchains network, providing a bridge between traditional financial systems and blockchain-based technologies. https://monerium.com/blog/2023/what-is-emoney/

[20] https://www.sanddollar.bs/about; https://www.norges bank.no/contentassets/fb85d452791d4d1a9f04aa4d3c18683d/norges-bank-papers-2---phase-4---final-report.pdf?v=18122023133556; https://www.ledgerinsights.com/national-bank-of-denmark-cash-retail-cbdc/; Central Bank of Iceland, *Rafkróna? Central bank digital currency Interim Report*, Special Publication No 12, 2018.

[21] Auer, R., & Böhme, R. (2020) op. cit.

balances managed locally, but this structure would be more difficult to implement. As stated above, most of CB are considering a retail CBDC architecture that involves the private sector as an intermediary. This system would comprise the central bank, operator(s), participating PSPs and banks. A wider ecosystem supporting the structure could then include data service providers, companies providing and maintaining applications and providers of point-of-sale devices to initiate and accept payments. Since CPMI-MC 2018 funding paper, in which it foresees KYC, AML/CFT roles switch to the central banks, nowadays the general idea is that the private sector would carry on the KYC requirements and AML/CTF procedures. 60% of the CBs think that the recording and updating retail transaction and balances could be left to private sector. Private financial institutions will basically maintain the current role as for the cash. But intermediaries can run into difficulties and insolvency, so that a risk to the resilience of the structure if the intermediary manage a key feature. For what concerns the costs of these private sector intervention we will further discuss on the paragraph regarding the stakeholders.

2) *Payment authentication:*

How transaction is verified, could be:

- *i) Identity based, i.e. requires user identification/account holder verification. This could be part of the KYC procedure or the transaction monitoring requirements;*
- *ii) Token-based, in which transactions are authenticated via tokens or digital signatures.*
- *iii) Multifactor, which combines multiple methods for strong security framework.*

From the consumer point of view this means who can have access to CBDC, i.e. whether issue a CBDC account based or token based. The former is linked to user identity, good for strong law enforcement and functioning payments, but the unbanked and cash relying individuals would remain out. Token based does not essentially rely on the verified identity of the users but in the authenticity of the token, that however could bring counterfeiting and illicit risks.

Authentication method will determine the data structure of the CBDC, its integration with other systems and the privacy levels provided to users.

3) *Functionality:*

A ledger could be a simple record of central bank liabilities or incorporate more sophisticated functions, such real time synchronizing across different financial institutions, that would address a wider adoption however would increase costs and limit differentiation between service providers. Some of these enhanced functionalities can be found in Smart Contracts and Atomic Transaction. The first is a programmable protocol through which automate various financial transaction once some predefined conditions are met. The second regards a set of linked transactions that are either all complete successfully or none do. This is very important in complex securities settlements or cross-border payments.

Of course, more functionalities can lead to a greater adoption because CBDC would not be just a digital cash equivalent, but at the same time the more sophisticated the system is the more the regulatory compliance would be and greater the costs.

4) *Access requirements:*

Meaning which entities can read and operate on the ledger. Can be divided in read access and write access. Read access defines who can view and balance data in the ledger, and can range from public to private systems. Logically, a public access ledger ensures transparency but may compromise privacy. Write access involves who can validate the transactions, usually CB and regulators, financial institutions and PSPs and third-party developers.

5) *Governance:*

In a CBDC system a rulebook will be need to address roles and responsibilities for of the operator, participants, stakeholders and service providers, how the interoperability between those actors will be managed, additionally how central banks will act regarding data-sharing and privacy. This rulebook must comply with national and international laws.[22]

1.3.2.1 Centralized and DLT ledger

[22] BIS "Foundational Principles" 2020; Auer, R., & Böhme, R. (2020) op. cit.; Auer, R., Cornelli, G., Frost, J., (2020) op. cit.

Ledger is the infrastructural backbone of a CBDC design. It can use a centralized ledger or a distributed ledger. A Conventional ledger or central ledger is a comprehensive record of all the financial transactions and balances of a company or an entity. It has a centralized architecture with a single authority or organization controlling access and updates to the data (DBA, Database administrator). The ledger is typically stored in a central database or server with which user can interact to perform transaction and retrieve information. Central authority is trusted by all participants to maintain the ledger. These ledgers can be easier to manage and can assure greater scalability. Even though safe, they are vulnerable to technical failures, hacks and single point of failure, that refers to system configuration in which a single element can disrupt the database operations.[23]

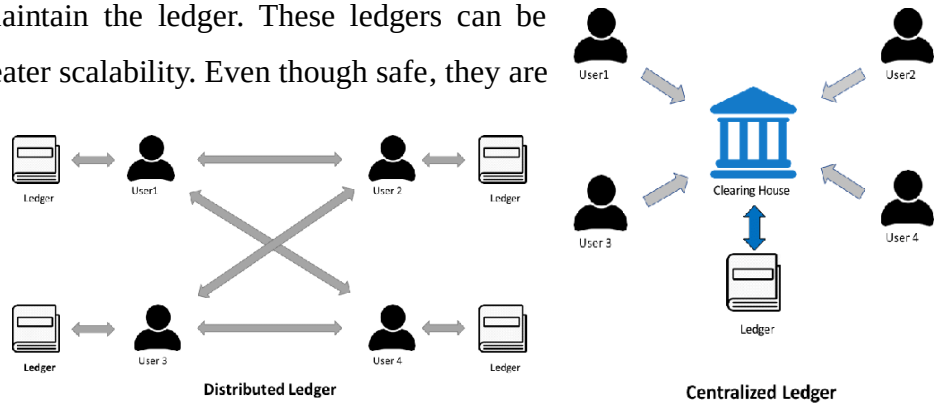


Figure 5 and 6 About Centralized and Distributed Ledger. Source: Suvarna K. Kadam, Review of Distributed Ledgers: The technological Advances behind cryptocurrency, Department of Computer Engineering D. Y. Patil College of Engineering Akurdi, SPPU, Pune INDIA, 2018.

BIS defines DLT (Distributed Ledger Technology) as "the protocols and supporting infrastructure that allow computers in different locations to propose validate transactions and update records in a synchronized way across a network". The idea itself is not new, but traditional ledger has a system administrator which perform the key functions, holds the master copy and perform the updates then shared amongst the copies of the ledger. DLT ledgers are designed to function without a trusted authority. Cryptocurrencies such as Bitcoin "maintain a distributed database in a decentralized way by using a consensus-based validation procedure and cryptographic signatures.[24] In such systems, transactions are conducted in a peer-to-peer fashion and

[23] https://crypto.ro/en/dictionary/central-ledger/; Suvarna K. Kadam, *Review of Distributed Ledgers: The technological Advances behind cryptocurrency,* Department of Computer Engineering D. Y. Patil College of Engineering Akurdi, SPPU, Pune INDIA, 2018.

[24] Consensus Based Validation: process in DLT to achieve agreement between network participants on the validity of transactions. These transactions involve multiple nodes (computers) within the network validation the transactions. Once a majority of a specific threshold agrees that a transaction is valid is accepted and added on the ledger. The most common consensus algorithms include Proof of Work (PoW), Proof of Stake (PoS), Delegated Proof of Stake (DPoS).

Cryptographic Signatures: fundamental security feature used in digital transaction to verify the authenticity and integrity of messages or documents. It testifies that a transaction was created by a known and authorized

broadcast to the entire set of participants who work to validate them in batches known as "blocks"". Each block contains a batch of transactions, and each one is linked to the previous one, creating a record of all transactions in the network. [25]

DLTs face significant performance issues primarily due to the extensive computational resources required for their consensus protocols, particularly in systems that rely on mining, like those using Proof of Work (PoW). These protocols are integral as they ensure all participants in the decentralized network to agree on the ledger's current state without needing a central authority.[26] In public DLT networks, every transaction must be validated and agreed upon by multiple nodes (participants in the network), which can be computationally intensive, time-consuming and electricity consuming. This is because achieving consensus in such a decentralized environment often involves complex mathematical computations and can lead to congestion as the network scales up. PoW as validation systems, need to carry on complex calculations to find a valid nonce, a number used to solve the cryptographic puzzle. Once the network validates this new block the block in confirmed and added on the chain, rewarding the miners, i.e. the solvers of these puzzles, with newly issued cryptocurrency. This, even if result in a slow transaction throughput due to consensus mechanism complexity, it ensures protection against double spending and tampering, which is an unauthorized modification of the system, its components and/or the data there stored. This kind of DLT can be implemented for direct CBDC only in small jurisdictions with a controllable volume of data throughout.[27]

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party. A CS is generated using the sender's private key, which is kept secret. The signature can be verified by anyone using the sender's public key, which is openly available. The process ensures that the transaction is legitimate and that the sender cannot later deny having sent the transaction (non-repudiation). D. Drescher *Blockchain Basics, a Non-Technical Introduction in 25 Steps*; https://learn.microsoft.com/en-us/dotnet/standard/security/cryptographic-signatures.

[25] Bech, M. L., & Garratt, R., (2017), *op. cit.* p58.

[26] Ibidem;

[27] Ibidem; Makarov, I., & Schoar, A., *Cryptocurrencies and Decentralised Finance (DeFi)*, BIS Working Papers No 1061, 2022, pp.4-11; Ali, R., & Narula, N., *Redesigning digital money: What can we learn from a decade of cryptocurrencies?*, Digital Currency Initiative, MIT Media Lab, 2020, p.4 . https://en.wikipedia.org/wiki/Proof_of_work#:~:text=Proof%20of%20work%20(PoW)%20is,computational%20effort%20has%20been%20expended.; https://www.bis.org/publ/work1061.pdf; https://csrc.nist.gov/glossary/term/tampering#:~:text=An%20intentional%20but%20unauthorized%20act,its%20intended%20behavior%2C%20or%20data.; https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/the%20top%20trends%20in%20tech%20final/tech%20trends%20slides%2032%2033%2034

However, these challenges can be mitigated by using permissioned DLT networks. Unlike public DLTs, permissioned DLTs restrict who can participate in the consensus process, typically limiting it to a selected group of trusted nodes or validators, which are approved by a private firm o a consortium of institutions. This can significantly reduce the computational load and speed up transaction processing since fewer nodes participate in validating transactions. Permissioned networks can thus offer a more scalable alternative, suitable for handling higher transaction volumes, costs and with more predictable performance metrics.

The choice between using public versus permissioned DLTs involves trade-offs between decentralization and performance. While public DLTs offer higher degrees of decentralization and openness, permissioned DLTs can provide better performance and scalability but at the cost of centralizing some control which is why CBs exclusively experiment with permissioned DLT instead of the permissionless.[28]

Table 2. Potential Advantages of Centralized Databases versus Permissioned DLT

Advantages of Centralized Databases	Advantages of DLT (if implemented properly)
▪ Competencies more readily available for technology, security, and vendor relationship ▪ Better control of privacy ▪ Easier to scale ▪ Easier to upgrade ▪ Large available product base built on top	▪ More resilient by design if no single point of failure is introduced ▪ Offers new governance options ▪ Central bank does not have to hold any private data ▪ Could increase compatibility with DLT-based tokenized financial assets ▪ Innovative domain, with new solutions emerging from decentralized finance

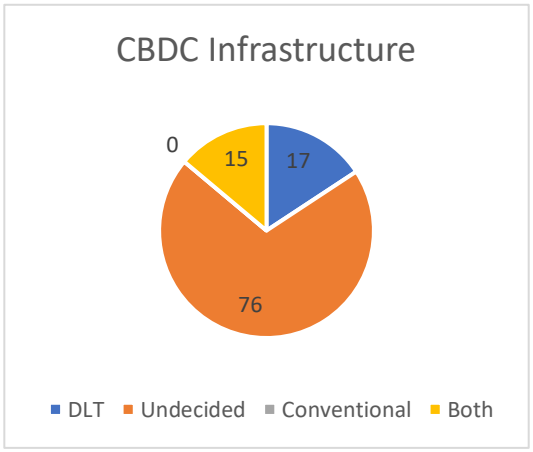
Source: Authors. Note: DLT = distributed ledger technology.

Table 2 On Advantages of centralized databases vs permissioned DLT. Source: Soderberg, G., et al. IMF Fintech Notes How Should Central Banks Explore Central Bank Digital Currency? A Dynamic Decision-Making Framework, IMF, 2023, Table 2

Back from this brief introduction on DLTs, let's compare the advantages and disadvantages of a centralized ledger against a permissioned DLT. One of the main differences is that Centralized database doesn't have a consensus mechanism but rely on a trusted authority. Permissioned DLT doesn't rely on central authority but there's a selection on who is taking part in the selection process. CB and commercial banks already rely on centralized ledger, they would therefore have to bear the cost of the transition if switching, nonetheless Central Banks would have to bear the cost to administer all set of duties that currently are not responsible for. Secondly, they'll have to define who will have access to the ledger, nonetheless the regulation of the CB authority over the balance sheet. DLT would be more resilient over Centralized Databases. Centralized ledger top vulnerability resides in top node failure and single point of failure, in DLT system

[28] Kuhn, R., Yaga, D., & Voas, J., *Rethinking Distributed Ledger Technology*. *IEEE Computer*, 52(2), 68-72. National Institute of Standards and Technology (NIST), 2019.

is a failure in the Consensus mechanism. Other advantages could arise from new governance options and an increased compatibility with other DLT-based financial asset platform.[29]



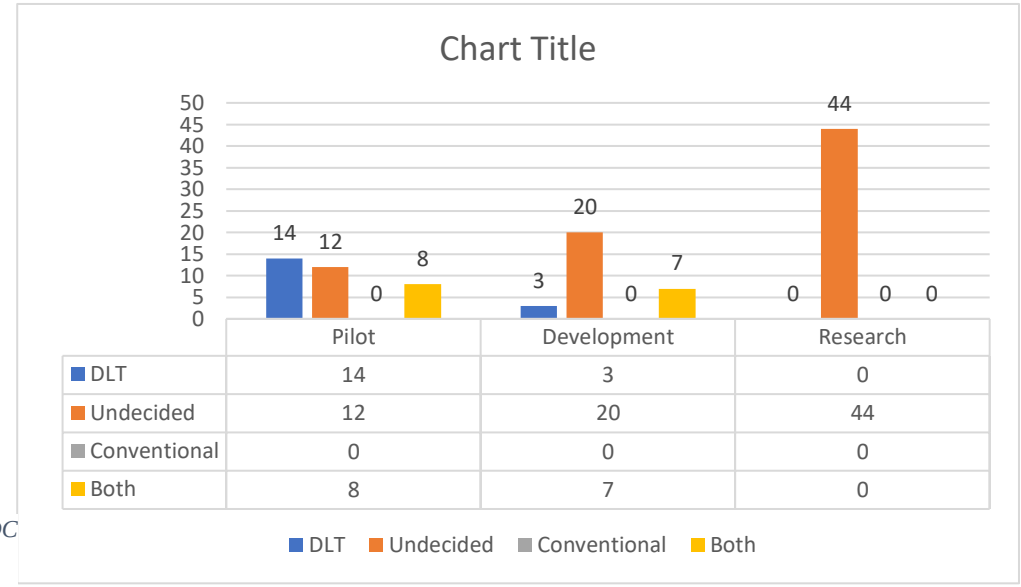


Figure 7 and 8 Source: Atlantic Council CBDC tracker. Author's elaboration

Data shows that the great majority of the active CBDC projects are still uncertain of what ledger to adopt in their infrastructure. For what concerns the canceled projects, Senegal had tried with a conventional centralized ledger, while Ecuador didn't eventually decide. Looking at the three launched currencies, Bahamas is using both, Jamaica adopted a conventional infrastructure, integrating it with the current payment system infrastructure. Nigeria uses a form of private blockchain which is not open to the public, therefore no statistic is available to consultations beside the CBN. This, aligned to the accusation of despotic monitoring of the country's financial system, people money and transactions, made the eNaira unpopular within the Nigerian population. CBN published in late 2023 a press release ensuring that eNaira is no threat to financial stability, linking a substantial 350 pages paper: "Economics of Digital Currencies", to try to relaunch eNaira trustability.[30]

1.3.2.2 CBDC Technology

[29] *Soderberg, G., Kiff, J., et al., How Should Central Banks Explore Central Bank Digital Currency? A Dynamic Decision-Making Framework. FINTECH NOTE/2023/008, IMF, 2023. pp.20-23*; Auer, R.& Böhme, R. (2020) op. cit. p. 9; Auer, R., Frost, J., Gambacorta, L., Monnet, C., Rice, T., & Shin, H. S., *Central bank digital currencies: motives, economic implications and the research frontier*, BIS Working Papers No 976, 2021.

[30] https://boj.org.jm/a-primer-on-bojs-central-bank-digital-currency/;https://www.atlanticcouncil.org/cbdctracker/; https://business.cornell.edu/hub/2023/04/28/nigerias-enaira-cbdc-what-went-wrong/

Technology for CBDC doesn't limit on the infrastructure and ledger choices, it has to cope with software's interfaces, transaction processes and security mechanisms. Ledger is only one fundamental part of it, because from record keeping choice derives security and privacy concerns as well as balances and transaction management efficiency. Research is rich, active and complex. Multiples proof of concepts are carried on. ECB issued a call for applications for potential digital euros service providers, comprising intermediaries for facilitating payment transactions, payment information exchange and software development, results will be expected by the end of 2024. MIT together with Boston Federal Reserve published in 2022 their CBDC technical proof of concept. Even though they didn't assess CBDC policy regulation, privacy and legal framework matters they managed to handle 170000 transactions per second with high potential for scaling up. Project Hamilton researchers published an OpenCBDC platform to allow every expert to freely participate in the making. As stated previously in this thesis, we will not delve into the specificalities of CBDCs technologies, that are manifold, would stray from the path of this thesis' purposes and author's field of study. However, technology and service providers will be taken into account as stakeholders, so if not inquiring into technical specificalities we will consider what is technology providers role within stakeholders' structure.[31]

In the BIS paper that has been analyzed and integrated with subsequent papers, is said that there's still a general lack for CBDC technology trials, but affirms that will surely need a mixture of different technologies. Nonetheless provides 5 core features of a CBDC technological architecture:

1) Convenient: a tap to pay feature, for devices with NFC (Near Field Communication), that could simply use qr-codes to make payments; easy p2p and e-commerce payments. Possibility of offline payments.
2) Secure and resilient: Users data protection will be carried by cryptographic methods. Privacy policy will be an important topic because a DLT system technology involves more complicated governance structures, and will need software solutions, that will be further discussed. Tamper-resistant hardware may be used to store data and ensure CBDC security. While a centralized ledger privacy policies will be simpler and more

[31] https://www.ecb.europa.eu/press/intro/news/html/ecb.mipnews240103_1.en.html; Lovejoy, J., Fields, C., et al. *A high Performance Payment Processing System Designed for Central Bank Digital Currencies,* Paper 22/163, 2022.

straightforward, the resilience that a DLT will ensure is unmatched compared to a few centralized data centers.

3) Fast and scalable: The system will require a high number of TPS (transactions per second) as well a big volume per user. This way the marginal costs will be minimized. DLT has shown difficulties in DLT public networking, but such problem could be marginalized through the usage of a permissioned DLT which will limit the nodes for the consensus process.
4) Interoperable: This feature will allow inter-account transactions in an interoperable environment. Third parties will adapt CBDC platform to the already existing channels. Iso 20022, as a data interchange standard for business processes as well, will enable interoperability in the payment processes. The possibility of change, as long as portability will be of primary importance to avoid being stuck to only one intermediary.
5) Flexible and adaptable: This will comply with the innovation requirements, i.e. make a CBDC currency and payment platform adaptable to the changes and the currents of payments, such changings in the cryptography or the nature of microtransactions.[32]

These features will face a pressure for a balance, faster payments vs strong security for instance. Another instance regards the offline payments and offline p2p transactions, which will further embroil the system because anti-fraud features are more difficult to implement in a distributed system, in which a possible cap on offline transactions would serve as a tradeoff solution for a centralized ledger, o a mixed one with more data centers. This would also increase the resilience of the system. The same cannot be said if a third party will bear a key function of CBDC, when in the sight of a malfunction the entire system would be compromised.[33]

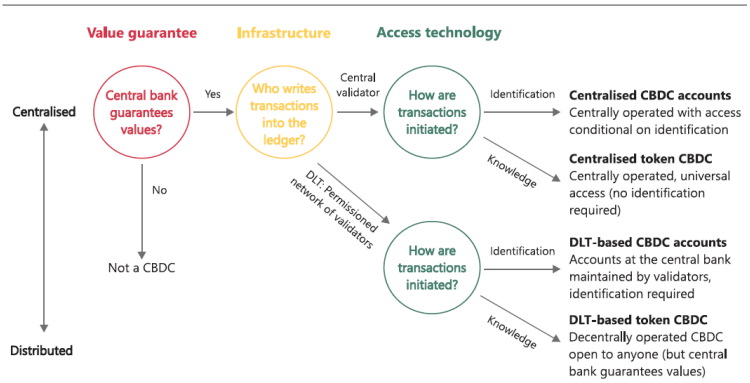
[32] Ibidem p.13-14; European Central Bank (ECB) *Report on a digital euro,* 2020.

[33] ECB (2020) op. cit.

1.3.3 Access Verification

Access verification is the last design defining choice. Figure 10 from BIS shows the process we followed for this structuring.

Considering the Garratt's (2017) so-called "money flower", there are three variants of CBDC: the retail-account based variant, the retail-token based and the wholesale token- or value-based one. The aim of this research points toward only on the first two variants.



This graph maps out the four possible combinations of whether a CBDC infrastructure is distributed or centralised and whether access is based on identification (accounts) or cryptographic knowledge (digital tokens). All four combinations are possible for any CBDC architecture (indirect, direct or hybrid), but in the different architectures, the central bank and the private sector operate different parts of the respective infrastructure.

Source: Authors' elaboration.

Figure 9 Source : Auer R., & Böhme (2020) Graph 3 p.93.

1) <u>General purpose account-based</u>: The system's effectiveness relies on its capacity to authenticate the identity of the account holder. Proper identification is crucial to accurately associate payers and recipients and verify their respective account histories. A significant issue is identity theft, which enables unauthorized transfers or withdrawals of funds.

2) <u>General purpose token-based</u>: Token-based money rely on the ability of the payee to verify the validity of the payment, i.e. in the digital system the "reality" of the coin electronic counterfeiting and if the said money it has already being spent (double spending problem).[34]

As we can notice the main difference resides in the degree of verification needed in order to carry on a payment. This fundamental design choice lays the foundation of the general CBDC architecture, payment structure and technological infrastructure, that will then reverberate on the monetary and financial system, and will need to set the legal *ad-hoc* framework regulation and privacy concern choices. A token-based system would ensure universal access and privacy whereas the account one may hinder financial inclusion of the already unbanked and threat user privacy. Account based, on the other hand, are safer, don't rely exclusively on private key secret and can carry on easier AML/CFT framework, as well as difficulty to keep track of money flows by law enforcement authorities. As Figure 10 shows either account- or token-based could be centralized or permissioned-DLT ledged. [35]

[34] CPMI-MC (2018) op. cit. p.4.

[35] Auer, R., & Böhme, R., (2020) *op. cit.* p.92; Auer, R., Cornelli, G., Frost, J., (2020) op. cit. *p.21*; Leucci, S., Attoresi, M., Lareo, X (2022) op. cit.; CPMI-MC (2018) op.cit.; Bech & Garratt (2017) op. cit..

1.4 Legal framework and privacy concerns

These two paragraphs will provide a general overview on CBDC legal framework and the privacy tenets that will constitute them, that happens to be the main apprehension for the future users.

1.4.1 Legal Framework

BIS notice that a prerequisite for issuing a CBDC is that the central bank has the authority to do so. 2021 data shows an 8% from 2020 survey, moreover 10% of the jurisdictions are currently changing their laws. Still 25% lack of the legal authority to issue a CBDC and 40% are unsure.[36] IMF states that a proper legal framework is vital to ensure accountability, transparency and financial stability over the central bank's role. So, first of all a country jurisdiction has to know whether has the legal basis to issue CBDC or what adjustments has to implement. There should be authorization to i) a function in the CB law to issue such digital currency ii) the power to produce, acquire, distribute and destroy token-based CBDC iii) explicit power to open accounts to all intended users of the account-based. CB should also keep a certain degree of flexibility to modify design choices during CBDC pilots.[37]

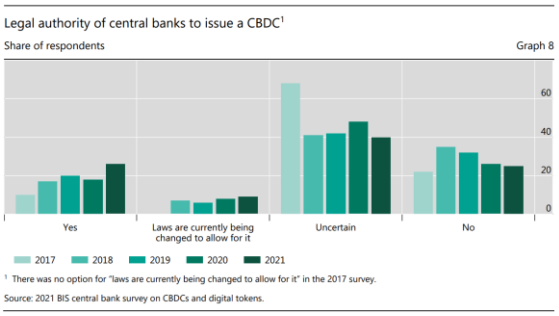


Figure 10 Source: Kosse, A., Mattei, I., Making Headway – Results of the 2022 BIS survey on central bank digital currencies and crypto, BIS Papers No 136 2023.

IMF Fintech note states that in order to legally sanction a CBDC several mechanisms should be established:

1) *Monopoly of issuance for the state: in most jurisdictions this provision grants the CB the exclusive right to issue currency.*
2) *Cours forcé: concept developed for banknotes, meaning that they would be accepted at face value, without convertibility into gold.*

[36] Kosse, A., & Mattei, I. (2023) op. cit.

[37] Soderberg, G., Kiff, J., et al., (2023) op. cit. p.24.

3) *Legal tender status: referring to the legal power of a currency to extinguish monetary obligation. In case of CBDC to treat the currency on par with banknotes, therefore considered of the same legal basis.*
4) *Privileges under private law: approved payments instruments granted by private law, to promote its use as a mean of payment.*
5) *Protection under criminal law: protection of sanctioned means of payment by imposing criminal law sanctions on those who counterfeit, damage, or destroy those instruments.*

These legal requirements have to be consistent with the existing legal mechanisms, like the TFEU for the European region. ECB states that the legal basis has to look over the design and purposes of a CBDC. Regarding CBDC access base, if it's account-based it would follow private nations law governing bank deposits, if it's token-based there will be a claim on the central bank incorporated in a digital token, a transfer of the token is equal to a transfer of the claim. So proper regulations in the relationship between the issuer and the account holder, and/or the private intermediary, the account holder and the central bank if it's a two-tier system.[38]

The CMPI and the International Organization of Securities Commission have set Principles for Financial Market Infrastructure, which CBDC must comply with. It oversees that payment systems and instruments will ensure clear legal relationship between the stakeholders. Before issue a CBDC, jurisdictions have to assess potential risks to financial integrity, predict and adapt to the design choice to the possible AML/CFT threats, for which a supervisory expertise can be deployed.[39]

Another IMF paper states that important adjustments must be ordered if a retail CBDC would be implemented for cross-border payments. Country legal and regulatory requirements should comply to global standards of privacy and anonymity, cut down settlement risk for cross currency trades and for probabilistic finality in DLT technology use realm, maybe using PvP settlement[40] function in order to reduce the counterparty risk.[41]

[38] *Id.* pp.24-26; ECB (2020)

[39] *Id. pp.* 26-28.

[40] PvP settlement: "PvP (payment versus payment) is a settlement mechanism that serves to reduce settlement risk in FX post-trade processing […] ensures that final settlement of a payment in one currency occurs if and only if the final settlement of a payment in the other currency takes place. From: https://bis.org/cpmi/publ/d216.pdf

1.4.2 Privacy implications

2021 ECB published the results on its public consultation on digital euro, showing that professionals and citizens both considered privacy as the most important feature of digital euro (43%). Auer et al. as well as the CPMI-MC underline the fact that the scale wavers between identity and anonymity, national security actions against AML/CFT and double spending through identity providing/verification or token authenticity: an account based or a token based CBDC. To use Auer et al. words "a tradeoff between privacy and ease of access on the one and ease of law enforcement on the other".[42]

Jiang J. assesses Solove's pragmatic approach and Niessenbaum's contextual integrity as suitable in order to address privacy in CBDCs.[43] Solove's pragmatic approach emphasizes the contextual and the dynamic nature of privacy. Affirms that when there's a disruption of practices and habitus, a privacy concerns arises. '"Privacy" is a general term that refers to the practices we want to protect and to the protections against disruptions to these practices.[44]

Not only a space in which be left alone, in which be shielded from the external examination and intrusion, a realm where individuals can shape their identities (Julie Cohen 2000).[45] This definition hardly adapts to digital world. Spaces, behaviors and activities traditionally considered private are boundless because the substrate concept of space changes, and subsequently the range of activities, behaviors and "locations".

Niessenbaum's contextual integrity resides in the "appropriate flow of personal information", depending on the context/situation in which the information is transmitted, to whom is transmitted, i.e. the actors involved, if one way or binary or even if third external actors are involved, what is actually shared, and last what is the principle behind the

[41] IFM Fintech Notes Cross-Border Payments with Retail Central Bank Digital Currencies Design and Policy Considerations André Reslow, Gabriel Soderberg, and Natsuki Tsuda

[42]European Central Bank (ECB) *Eurosystem Report on the Public Consultation on a Digital Euro*, 2021;, Kosse, A., & Mattei, I. (2023) op. cit.

[43] Jiang, J., *Privacy Implications of Central Bank Digital Currency*, Seton Hall Law Review, 54, 69-102, 2023.

[44] Daniel J. Solove, *Conceptualizing Privacy*, 90 CALIF. L. REV. 1087, 1088 (2002), p, 1093

[45] Cohen, J., *Examined Lives: Informational Privacy and the Subject as Object*, Stanford Law Review, 52(5), 1373-1423, 2000.

functionality. The context, as well as the underlying reason on the sharing determines the amount of information, recipients, distribution entity is acceptable for data to be shared.[46]

In the CBDC payment context the "external intrusion" could be very subjective. This is why to be pragmatic there's the need to some contextual elucidations. Four actors are involved in the payment: payor, payee, entities that carry out the payment, law enforcement agencies ensuring the legitimacy of the transaction. The information will include: payor and payee names, phones, addresses, profession, account balances, date and location of the payment, which entities processed the payment. Each entity involved in the payment will have a different degree of data access. The conception of the entity right to access and use those data, as well as what is considered private (non-disclosable) varies depending on the jurisdiction.[47]

Jiang J. article stresses on the operational model. As already stated, the operational model determines how CBDC are distributed which could be one-tier or two-tier operation model. The infrastructure regards the ledger system that will be implemented, whether centralized or distributed (DLT). However, it argues that the design of the verification object (account-based or token-based model) is not a critical foundational design choice as the two just stated. In the one-tier model the Central Bank will collect all the users' relevant information stated above, and will have a copy of the transaction details. Data will flow among the different departments within the central bank in charge to carry out the different tasks. In the two-tier model data mainly flows between the intermediaries, which will also handle communications with the end users. Intermediaries will have a copy of transaction details, if not obfuscated by ZKP mechanisms.[48] Depending on the design the CB can have a copy of the retail holdings or the retail balance sheet.[49]

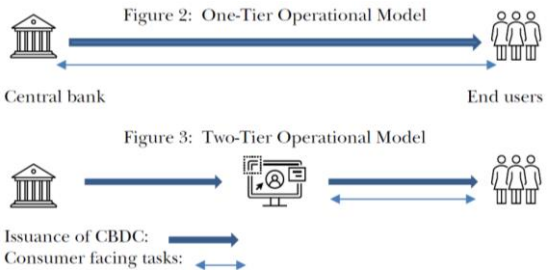


Figure 11 Source: Jiang, J., Privacy Implications of Central Bank Digital Currency, Seton Hall Law Review, 54, 69-102, 2023.

For Jiang J. the one-tier model raises three privacy concerns:

[46] Jiang (2023) op.cit.

[47] *Ibidem* 99-105

[48] ZKP: Zero-Knowledge proof is a cryptographic method that allows one party (a prover) to prove to another party (the verifier) that they know a certain information without revealing the information itself. https://en.wikipedia.org/wiki/Zero-knowledge_proof

[49] *Ibidem 108*

1) Mass surveillance:

   In this frame central banks will have a dominant position, because they will both have the storage of the information and at the same time the power to decide how to use this data. This could influence the consumers behavior due to the feeling of being constantly monitored. Jiang J. article disagree with this statement toward CBDC. It states that in democratic countries the CB is a separate and independent entity from the Government and have to comply to its constitutional mandate, having therefore no interest in exploiting personal data for profit.[50] Moreover, CB needs aggregated data to understand the macroeconomic trends, making identifiable personal data useless for CB purposes. However, even if each jurisdiction may have different stances on what to consider invasion of privacy, mass surveillance refers to a continuous, thus illicit, state of monitoring;

2) Cybersecurity risk:

   In one-tier framework data are store within a single entity, therefore there's more risk of breach for data appropriation.

3) Potential data misuse and abuse by other government authorities:

   Without the implementation of clear rules on data share and management within government agencies can lead to data leak and secondary use.[51]

Two-tier model presents two privacy concerns:

1) Increased number of data collection points:

   Intermediaries could combine CBDC data with other financial and personal data creating comprehensive personal profiles. They may share these data to external entities, enhancing data misuse or abuse, and since the data are sourced in multiple locations is more complicated to detect the outflow.

2) Increased cybersecurity risks at each of these collection points:

   Each intermediary uses its cybersecurity measures. The weaker ones are more vulnerable to attacks. Main difference with the one-tier is that the attacker would access only the data stored by that intermediary. This is the case of a hybrid architecture, where the CB is the holder of the CBDC users accounts and

[50] Brunnermeier, M., & Landau, J. P., *The digital euro: policy implications and perspectives*, European Parliament Policy Department for Economic, Scientific and Quality of Life Policies, 2022 p.25.

[51] *Id.* pp.109-112.

intermediaries has only partial data. But here the problem of the one-tier would arise again.[52]

Permissioned DLT infrastructure arise another privacy concern. Since it grants intermediaries a copy of the ledger to perform the consensus process. Here, "a breach of a single intermediary's end can expose all the CBDC dataset", increasing exposition compared to conventional two-layer architecture. It's also true that users' identities are encrypted, but as transactional activity amplifies, also in the context of programmable money, it become easier to decrypt user's identity.[53] Jiang J. Concludes asserting that ex ante privacy solutions are better than ex post. This means that they have to be assessed while designing a CBDC or even before, using a "User centered method" in which designers come into contact with the future users in the very beginning of the project. ZKP for fully anonym cash-like CBDC is most likely unachievable, because even if some proofs of concept are proposed, they are not compliant with AML/CFT regulations.[54]

Differently, Auer and Böhme stress more on the access base to investigate privacy implications. Account-based would intrinsically embed to one and only one identity, which would be private but not anonym, and token-based which can be both buy not compliant with KYC, AML/CFT regulations, can run into difficulties to track payments and claiming owners' verification. Apart from that, if a certain amount of information like the ones stated above should be concealed between users, thus using pseudonyms, and to front-end applications, like smartphone payment app. Moreover, whoever is that holds such data must possess users' trust, and this trust may differ from jurisdictions and citizens, leaning trust more on government and institutional entities or on private entities. Ultimately, even if the safest way would be not to keep data at all, is clear that they must be collected and stored so a solution against breaches and leaks is needed. Encryption, anonymization and separated, physical offline storage can be the solutions.[55]

BIS in collaboration with Hong Kong Monetary Authority (HKMA) created Project Aurum, a prototype for a two-tier retail CBDC. Here the KYC is implemented by the intermediaries. Not the Validator (the CB), nor other parties involved in the transaction hold

[52] *Id. pp.* 112-117.

[53] *Ibidem* 117-119.

[54] *Ibidem* 119-135.

[55] Auer & Böhme (2020) op. cit. pp.93-94.

user's personal information. Its identity is encrypted by using pseudonyms and pseudonym public keys during transactions.[56]

ECB (2023) also states that Eurosystem wouldn't be to identify any natural person making or receiving digital euro payments. The solution proposed is through pseudonymization and clear segregation of personal data PSP, service providers and Eurosystem. Offline payments will not involve sharing transaction data to PSPs, Eurosystem or any service provider, except for what concerns forgery. For what concerns online digital euro payments it would be consistent with current legislation applicable for electronic payments and data protection, privacy and AML/CFT rules. Data available to Eurosystem to perform related tasks will be pseudonymized.[57] Another ECB working paper (2024) also states as Jiang that public digital money will have a comparative advantage at providing privacy because are not bound to a profit incentive. ECB (2023) and Bank of England (2023) will put users in power of decide whether and how their personal data will be processed by PSPs for commercial purposes.[58]

1.5 Stakeholders

Stakeholders may differ slightly whether retail or wholesale CBDC are taken into consideration. Since this research looks into retail CBDC, I will focus only on those stakeholders and their possible effect for them, i.e. in monetary policy, financial equilibrium legal and managerial concerns.

Data shows that EMDE are more advanced in projects, pilots and issuing than AEs. Nearly 93% of central banks are collaborating with external stakeholders to inform design choices. The engagement of stakeholders is larger in AEs than in EMDEs, and generally more common for retail CBDC than wholesale. For retail CBDC central banks are engaging or working mainly with their governments and/or other public authorities, external technology providers and other private sector entities, such as commercial banks. Bank of Canada

[56] BIS Innovation Hub, *Project Autum: A Prototype for Two-tier Central Bank Digital Currency (CBDC),* BIS Innovation Hub Report, 2022, pp. 11-13.

[57] European Central Bank (ECB), *A Stocktake on the Digital Euro: Summary Report on the Investigation Phase and Outlook on the Next Phase*, 2023. pp. 35-39.

[58] Ibidem; Ahnert, T., Hoffmann, P., & Monnet, C., *Payments and Privacy in the Digital Economy,* ECB Working Paper Series No 2662/2022, Revised June 2024; Bank of England, *The Digital Pound: Technology Working Paper,* 2023.

engaged discussions with end users and various stakeholders, such as private financial institutions, commercial banks, society groups and questionnaires to the citizens to understand what are the necessaries features of a CBDC and the potential risks involved in the issuing.[59]

Analyzing the available literature, based on IMF paper "*How Should Central Banks Explore Central Bank Digital Currency*?" already consulted in this thesis, six CBDC key stakeholders are detected.[60] These stakeholders are intrinsically connected, therefore the activities, and the subsequent effects ripple through each other. They are: central banks; governments; commercial banks and financial institutions; consumers and business and merchants (put together since their interests and risks coincide); technology and service payment providers; international institutions.

1.5.1 Central Banks

CB are the principal CBDC stakeholder. They are the issuers and the regulators of CBDCs. They are responsible to manage the monetary policy, financial stability concerns, financial inclusion and, depending on the structural design, also the ledger. Their major risk resides in the potential disintermediation for commercial banks, along with the cybersecurity threats, AML, counterfeit risks.[61]

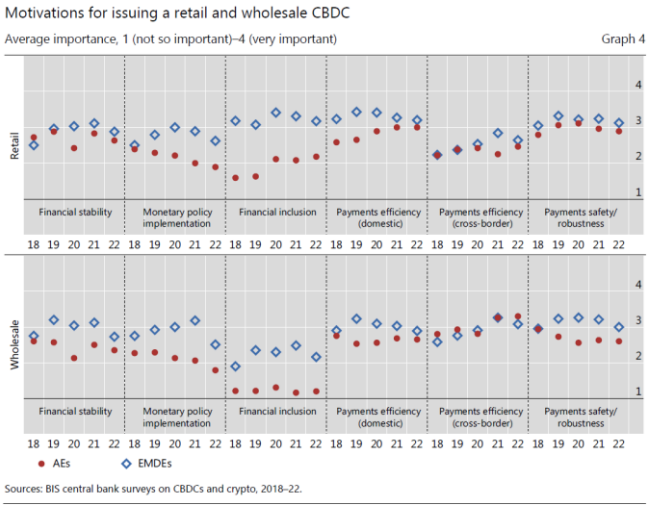


Figure 12 from BIS Paper 125: Gaining momentum – Results of the 2021 BIS survey on central bank digital currencies by Anneke Kosse and Ilaria Mattei.

A BIS paper shows that the motivation for issuing a CBDC could differ whether the issuer is a EMDE or an AE. [62] EMDEs, for retail CBDC are more prone to a CBDC for financial inclusion and stability, for payments efficiency and safety, where AEs are more concerned payments efficiency (domestic), payment safety and for financial inclusion.[63]

[59] Kosse, A. & Mattei, I. (2023) op. cit. p.12.

[60] Soderberg, G., Kiff, J., et al. (2023) op. cit. p.16.

[61] BIS (2020) "Foundational Principles" op. cit.; Auer, R., Cornelli, G., & Frost, J. (2020) op. cit.; Auer & Böhme (2020) op. cit.

[62] Kosse, A & Mattei, I., (2023) op. cit. pp. 8-9.

[63] *Id.*

However, as Auer et al. demonstrates, CBDC development is embedded to internet permeation, mobile usage and innovation, hence the need for a developed digital infrastructure, usually an unmatching characteristic whereas there's more need for CBDC for financial inclusion.[64]

Apart from that, the reasons for central banks to issue a digital currency can be divided in 1) payment motivations 2) public policy motivations and 3) other motivations.

1.5.1.1 Payment Motivations

1) Guaranteed public access to central bank money. To be a complementary system where cash usage is in decline.[65]
2) Resilience:

   Backup method for cash in places where access to cash is marginalized, both for geographical of natural disaster reasons. In this frame CBDC would act as an additional payment method that could operate, at least theoretically, also offline.

   Nonetheless, the risks from cyberattacks would need robust security measures due to the increased number of potential entry points compared to traditional banking systems.
3) Increased Payments diversity:

   Payment systems benefiting from strong network effects might lead to monopolies or fragmented markets. A CBDC could act as an interoperable medium that facilitates transactions across different systems, helping to mitigate the dominance of major players and reducing the inefficiencies associated with fragmented payment services.
4) Promoting Financial Inclusion:

   As society becomes more digital, certain groups might be left behind due to barriers like lack of digital skills, trust issues, or privacy concerns. CBDCs are viewed as a potential means to enhance financial access, particularly in developing regions. Effective implementation would require integrating CBDC efforts with broader policy reforms aimed at addressing these fundamental barriers.
5) Enhancing International Payments:

[64] Auer, R., Cornelli, G., & Frost, J. (2020). op. cit. p.14.

[65] This was the main reason for the Sveriges Riksbank (2018) to issue its e-Krona (see update).

International payments are typically slow and costly, complicated by the need to navigate multiple intermediaries and regulatory systems. A widely compatible CBDC could simplify and expedite these processes, making global transactions more straightforward and less expensive.

6) Ensuring Privacy in Public Transactions:

Unlike cash, which allows anonymous transactions, a CBDC would create traceable records of financial activities. Designing a CBDC system involves balancing privacy concerns with compliance with regulations such as anti-money laundering. This requires thoughtful policy development concerning who can access transaction data and under what conditions.

7) Streamlining Government Payments:

The pandemic has shown the potential for CBDCs to facilitate efficient government payments to citizens during emergencies. For effectiveness, such systems would need to be linked to a comprehensive digital identity network. There is, however, a concern that using CBDCs for government disbursements could blur the distinctions between monetary and fiscal policy, potentially affecting the autonomy of monetary policy strategies.[66]

8) Remittances payment:

Some countries like Tunisia are developing its digital currency also for a domestic and cross-border low-cost remittances payment.[67]

1.5.1.2 Monetary Policy motivations

Monetary policy motivations are not paramount in the reason to issue a CBDC, however the implications would be critical.

1) Information retrieving:

Being digital per nature a CBDC infrastructure system can provide CB many information regarding the economy, monetary flow and spending habits of users.

[66] BIS (2020) "Foundational Principles" op. cit. pp. 5-7; Mancini-Griffoli, T., Peria, M. S. M., Agur, I., Ari, A., Kiff, J., Popescu, A., & Rochon, C., *Casting Light on Central Bank Digital Currency,* IMF Staff Discussion Notes, SDN/18/08, 2018.

[67] https://www.atlanticcouncil.org/cbdctracker/; Bouza, S., Miccoli, M., & Mircheva, B., *Central Bank Digital Currencies Can Boost Middle East's Financial Inclusion, Payment Efficiency,* IMF Blog, 2024.

2) Direct targeted transfers to the people:

CBDC could be a way to stimulate aggregate demand through direct transfers to the public, together with the so-called "programmable monetary policy" in which money are distributed with an expiry date to buy specific goods, with immediate impact or to support certain sectors. This will need to clearly identify the recipients in need of financial sustain and bridge a link to their account, a first remarkable challenge. Moreover, this will have great impact in the monetary policy because it would lead into an overlap between fiscal and monetary policy.

However, the aforementioned possibility could be attainable through the existing channels, therefore it questions the real necessity of a CBDC for monetary policy.

3) Andolfatto, Chiu et al. state that a CBDC with a low interest rate can improve allocative efficiency.[68]

Depending on the entity of the issuance and the adoption it could influence the way how central banks do their balance sheets to influence short-term interest rates. In order to compensate the inflows or outflows of CBDC, they will have to conduct operation in the open market (OMOs) to inject or absorb liquidity maintaining the desired level of reserves.[69] ECB states that is preferrable for the CB to maintain a positive level of reserves, in order to ensure a smooth implementation of monetary policy.[70]

1.5.1.3 Monetary policy risks:

1) "Digital dollarization" risk/monetary sovereign risk:

   It implies that mass adoption of a digital currency, CBDC, crypto or stablecoin, i.e. not adopted by a country's CB can potentially undermine a country financial stability and effectiveness of monetary policies due to the decrease in the relevance and use of the sovereign currency. This is also one of the reasons that BIS addresses for countries motivation for issuing a CBDC, in order to "not be left behind" if other countries will issue its CBDC.

2) Risk of losing seigniorage:

[68] Andolfatto, D., *Assessing the Impact of Central Bank Digital Currency on Private Banks*. *The Economic Journal*, 131(634), 525-540, 2021; Chiu, J., et al., *Bank Market Power and Central Bank Digital Currency: Theory and Quantitative Assessment*, Chicago Journals, Journal of Political Economy 131 No 5, 2023.

[69] *Ibidem* p.8.

[70] ECB (2023) op. cit. p.23; Mancini-Griffoli, et al. (2018) op. cit.

Seigniorage is the income earned by a central bank from issuing banknotes. In a two-tier banking system part of the income from money issuing accrues to commercial banks. This risk has two main factors: the first regard the actual costs a central bank will have to bear in order to issue CBDC, distribute it and manage the payment infrastructure; the latter regards the shift from bank deposits toward central banks CBDC accounts, thus and a loss of a traditional commercial bank seigniorage income. Moreover, it must also be taken into account whether and the possible entity of decrease banknotes and coin seigniorage central bank income depending on the CBDC take-in and if (most probably not when looking at last published papers) will they be interest bearing.

3) CBDC costs:

Possible low operational expenses, significant infrastructure expenditures, but very low marginal costs. Everything comes with a cost, from issuing a CBDC to run it, process payments, ensuring continuous efficiency and innovation. Burden the cost toward user may hinder the willing adoption. To compensate for this central bank could designate CBDC as a public good allocating the profits made issuing a CBDC (seigniorage), offsetting the costs from the users. Another solution would be to charge the service providers, who would need to adapt their business models and able to stay competitive and innovative. They may end up to charge users toward service fees, subsidizing by public funding or giving access to consumer data, the latter one of the greatest concerns regarding CBDC.[71]

Table 4. Examples of Cost Structure in Different Phases of the Project

Preparation and Proof-of-Concept Phases	Prototype Phase	Pilot and Production Phase
▪ Small- to medium-size team ▪ Technology providers ▪ Workshops, hackathon ▪ Market research, conferences	▪ Core CBDC team (including payment, banking, supervision, legal) ▪ Software development (internal and vendors), platform acquisition, licenses ▪ Network infrastructure setup ▪ Cybersecurity	▪ Full-scale production team ▪ Full-scale research and development team ▪ Data security ▪ Security audits, testing ▪ Compliance assessment ▪ Training ▪ Ongoing maintenance and operation (such as systems monitoring, upgrades) ▪ User support, customer services ▪ Onboarding cost of new users and participants ▪ Ongoing fees for vendor involvement

Figure 13 Source: Tourpe, H., Lannquist, A., & Soderberg, G., A Guide to Central Bank Digital Currency Product Development: 5P Methodology and Research and Development, IMF Fintech Notes 2023/007, 2023. p.22

It's still not clear how much CBDC will cost for CB and/or its intermediaries. IMF (2022) however states that it would vary significantly across jurisdictions. CB are employing 10 to 300 staff members for

[71] CPMI-MC (2018) op. cit. p.14; BIS (2020) "Foundational Principles" op. cit. pp. 8-9.

their research. From proof of concept to prototype to pilot and production phase the teamwork will enlarge conspicuously.[72]

4) Further interventions:

   In the case that a reduction of bank holdings for CBDC lead to a reduction of reserves, CB could have to make some actions in order to provide some more. The amount of reserves is important for the short-term interest rate. Therefore these actions would be aimed at keep interest rates aligned to the intended monetary policy and to keep sufficient reserves in the case CBDC holders want to retrieve their money.[73]

5) Cross-border risks:

   In case FMI and other foreign institutions holding domestic CBDC, could result the equivalent of CBDCs offshore accounts. It would be then difficult to implement AML/CFT requirements in token-based. Substitution away from a domestic currency, a similar effect of "digital dollarization".

1.5.1.4 Other motivations

1) Keep the pace with the digitalization, as a response to changes in payments, finance and technology. However, contrary to the common sense in CBDC, exogenous introduction of more convenient payment methods led only to a moderate average reduction in the cash share of payments.[74] Financial institutions are generally skeptical on the potential benefits, since current payments options are oftentimes comfortable enough. It all depends on how the trends in payments and banking will evolve in the future. However, citizens and civil society groups enlighten on the fact that bank branches are closing in small towns, leading to more difficulties to open accounts or withdraw cash in some areas, mostly where great distances could hinder financial inclusivity.[75]

[72] Tourpe, H., Lannquist, A., & Soderberg, G., *A Guide to Central Bank Digital Currency Product Development: 5P Methodology and Research and Development*, IMF Fintech Notes 2023/007, 2023. p.22.

[73] *Ibidem.*

[74] Auer, R., Cornelli, G., Frost, J. (2020) op. cit.

[75] Bank of Canada, *What We Heard: Engaging with Financial Institutions on a Digital Canadian Dollar*, 2023, p.3.

2) Response to the crypto finance: Crypto assets and stablecoins may be a threat to financial stability, in the guise of digital dollarization.[76]
3) Keep timing with other issuing central banks: In order not to lose monetary sovereignty to other countries CBDCs, partly similar to the just mentioned digital dollarization for cryptocurrencies.
4) Foster international cooperation enhancing cross border payments, as acknowledged by the CPMI. BIS paper n.101 questionnaire result, however, report a least interest for cross-border payment efficiency in general purpose CBDC.[77]

As for the drivers Auer et al. pointed that those countries with more developed digital infrastructure, innovation capacity and institutional quality tend to be more likely toward a launch for a CBDC. And still, the demand for a CBDC may fulfill for different needs. Countries with higher GDP may have a higher demand for new digital payment methods, whereas jurisdictions with lower access to transaction accounts have a need for financial inclusion policies. Regarding cross-border transactions, there could be more need for trade openness of for an easing remittance system flow.[78]

Even though CB could have different motivations due to countries specificities and needs, they could also address to common objectives in order to facilitate the establishment of common ground requirements for CBDC (this in the vision of a cross-border CBDC activity).

1.5.1.5 Financial Stability concern

Now we look at the reasons why a Central Bank would refrain to pursuing a CBDC in the light of the financial threats may lead to.

1) Cyber security:

   This major concern for all stakeholders is currently one of the most important operational challenges for central bank systems and financial industry. Cyber-threats, such as malware, and fraud are risks for nearly every payment, clearing and settlement system. They pose, however, a particular challenge for a general purpose CBDC, which is open to many participants and points of attack. Moreover, the potential effect

[76] Kosse, A.& , Mattei, I (2023) op. cit.

[77] Barontini, C., & Holden, H., *Proceeding with Caution: A Survey on Central Bank Digital Currency*. BIS Papers No 1011, 2019, p.8.

[78] Auer, R., Cornelli, G., & Frost, J. (2020) op. cit.

of fraud could be more significant because of the ease with which large amounts could be transferred electronically. Robust mitigation methods of cyber-risk would therefore be a prerequisite for CBDC issuance.

2) Vehicle for financial crimes:

   Such as money laundering, terrorist financing, counterfeiting and double spending activities.

3) Potential disintermediation of banks and bank runs toward CBDC:

   This is considered a risk but also an opportunity to streamline payments, mostly for cross-border p2p and wholesale cross-border payments. Nevertheless, in time of financial distress there could be the risk of bank runs toward CBDC because considered safer asset, since they are a liability of the central bank. This concern will be more extensively considered later on when considering commercial banks as stakeholders, along with the solutions proposed.

4) Impact on market liquidity:

   CBDC are very liquid and convertible by definition. However, if the demand exceeds the decline in demand for cash or reserves, Central banks will have to increase the outright holdings that back the CBDCs that are issued. This can lead to a reduction in the "free-floating" share of bonds, thus decreasing market liquidity and affecting their price. Moreover, it could influence the Repo market. If CBDCs become a preferred way to holding liquidity as a secure asset by financial institutions, Central Bank will need to broaden its holding assets to match the liabilities, expanding the role of central banks, potentially influencing prices and yields in these markets, an eventually leading to a reduction in interbank activity and price discovery.[79]

5) If CBDCs will take off as a mean of payment, it would mean a shift toward central banks in financial intermediation, a role traditionally occupied by commercial banks. This could also influence the allocation of credit and liquidity in the economy. The more the demand for CBDCs will increase the more CBs will need to acquire more assets, such as government securities, ETFs, securitized mortgages, a path that could lead to holding riskier and less liquid securities and risking to affect market functioning. Moreover, Central Banks may be less efficient in allocating a potentially great amount of resources. CMPI-MC text underline the possible inefficiency of bank's direct involvement in holding corporate securities or other assets. A

[79] CPMI-MC (2018).

decentralized banking system in which private banks and financial institutions can make better economic decision depending on the local conditions.[80]

6) Risk of a "spending spree":

   In the context of a CBDC as a nominal asset, households could engage in a "spending spree" due to the concern that CBDC will lose its purchasing power in the future putting at further risk financial stability, price stability and allocative efficiency (Schilling et al 2020).[81]

   A broadening of central bank operations, an increase of acquiring of government securities could lead to a more volatile demand for these bonds depending on the demand of CBDC. A to pervasive influence of the central bank in securities market could lead to allocative distortions, potentially diminish market liquidity and role of the market in price setting and yields.[82]

1.5.2 Governments:

The motivations that can move governments to issue CBDC do not differ so much from the CBs ones. Government authorities will be of paramount importance for what concern CBDC regulations, and the involvement of financial ministries. They will allegedly make sure that CBDCs will comply to the existing legal frameworks assessing the consumers privacy concerns.

The primary reasons for governments to issue a CBDC are listed as follows:

1) Government may look to CBDC as a way to countermeasure big technology platforms that implement its own payment infrastructure, thus scattering digital payments possibilities or conversely creating monopolies.[83]

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[80] *Ibidem*;

[81] Fernández-Villaverde, J., Sanches, D., Schilling, L., & Uhlig, H., *Central bank digital currency: central banking for all?*, 2019.

[82] CPMI-MC (2018); BIS (2020) "Foundational Principles" pp.8-9; Auer, R., Frost, J., Gambacorta, L., Monnet, C., Rice, T., & Shin, H. S., *Central bank digital currencies: motives, economic implications and the research frontier*, BIS Working Papers No 976, 2021, pp. 17-20; Panetta, F., *The digital euro and the future of Europe's financial system,* Speech at the CEPR/BCE conference, 2023.

[83] Panetta, F., *The cost of not issuing a digital euro*. Speech at the CEPR-ECB Conference on *The Macroeconomic Implications of Central Bank Digital Currencies*, Frankfurt am Main, November 23,

2) As just considered of CBs issuing motivation, cryptocurrencies or other countries CBDC can undermine a country monetary sovereignty, thus hindering a country stability.
3) Through CBDC government could improve financial services, thus decreasing payment efficiency gap in domestic payments while increasing financial access (mostly for EMDEs like the Uruguayan e-Peso purposes but is also shared by Swedish e-Krona)[84]
4) CBDC for tax collection:

   It would optimize public spending and as already stated facilitate the direct citizen funding in moments of need. This last will optimize fiscal policy and the direct connection to the citizens in case of natural disasters, so that the government could instantly provide money directly to the people.[85]

   Wang (2022) asserts that tax evasion will be affected by CBDC depending on its design anonymity and interest rate. Respectively, the less anonym the more it reduces tax evasion. With regards of interest rates, high interest rates on CBDC deposit will positively affect tax revenue. Ohik Kwon et al. (2022) also state that a positive interest rate on CBDC holdings will positively affect tax revenues but we know that no CB is pursuing an interest bearing CBDC for the risks that could undermine financial stability.[86]

Logically, even if CBDC can be considered as a digital cash, transaction will be registered and in case of an account-based CBDC they will even be traceable in the event of some form of tax evasion is suspected. Therefore, it can be inferred that tax evasion will decrease proportionally CBDC take-up and use, to be compared also to the envisioned increase in in

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2023 .https://www.bancaditalia.it/pubblicazioni/interventi-governatore/integov2023/en-Panetta-CEPR-BCE23.11.2023.pdf?language_id=1

[84]Mancini-Griffoli,(2018).

[85] Mancini-Griffoli Id; Implementing a retail CBDC: Morales-Resendiz, R., et al., *Implementing a Retail CBDC: Lessons Learned and Key Insights*, 2022.

[86] Wang, Z., *Tax Compliance, Payment Choice, and Central Bank Digital Currency,* 2022 Kwon, O., Lee, S., & Park, J., *Central Bank Digital Currency, Tax Evasion, and Inflation Tax,* Economic Inquiry, 60(4), 1497–1519, 2022.

bank deposit if the proposed binding features between CBDC accounts with bank accounts will be implemented (see ECB 2023 in commercial banks paragraph).[87]

Governments should vest themselves to CBDC promotion and education amongst citizens though multiple media. They will clarify relatively to the matters that most concern direct retail users that are privacy concerns, application possibilities, tutoring activities on how to create its portfolio and how to use it, enhancing literacy while limiting political backfires.[88]

1.5.2.1. Risks

Risks can be pointed in personal data leaking and excessive surveillances concerns. These risks are shared between government and CB, even though vast majority of data will be kept by central bank and intermediaries, i.e. technology and payment providers.

1) Coordination problems might arise between the central bank and the government's debt management office, making it harder for the central bank to operate effectively (Greenwood et al (2014). If the central bank needs to manage high demand for CBDC, this could lead to unpredictable changes in government debt demand. Key issues include deciding which government body should handle short-term debt and manage the overall debt structure. If CBDC replaces a lot of bank deposits, the central bank might need to buy more government bonds, which could impact the debt market. Additionally, having a larger balance sheet might make it harder for the market to set prices correctly, causing inefficiencies and tying up valuable assets. This could disrupt collateral markets and affect overall financial stability.[89]
2) CBDC could lead to new tax evasion solution, more probably if would be of a token-based access verification. In an account-based it wouldn't be that easy if there are caps on accounts, and accounts are identity linked.
3) Another risk for governments could be political. If policies fail to capture people trust, which would refrain to adopt CBDC as a new mean of payment after many efforts and

[87] Rao, R., *Effects of Central Bank Digital Currency (CBDC) introduction on monetary policy and tax evasion*, PoliMi, 2022; ECB (2023).

[88] Ngo, V. M., et al., *Governance and Monetary Policy Impacts on Public Acceptance of CBDC Adoption*, 2022.

[89] CPMI-MC (2018) op. cit. p.15; Greenwood, R., Hanson, S., Rudolph, J., & Summers, L., *Government Debt Management at the Zero Lower Bound*, Hutchins Centre on Fiscal & Monetary Policy at Brookings, Working Papers, No. 5, 2014.

public spending in design, structuring and promotion, party opposites could take these fails to undermine governmental stability

1.5.3 Commercial Banks and Financial Institutions:

These entities will deal with the distribution of CBDC to the public and the subsequent integration in the financial system. They'll have to integrate their business models, such as deposits and payment services, and also their balance sheets in order to not offset the balance and contain spillovers and possible negative effects/financial instabilities.[90]

1) Keep intermediation role: With a hybrid/two tier architecture commercial banks and PSP will be responsible of handling payments, carry on AML/CFT and KYC requirements. Chiu and Davoodalhosseini (2021) attest that an interest-bearing CBDC can increase bank intermediation even in a competitive banking sector.[91]
2) Possibility of deposits increase: ECB (2023) states that the feared run from bank deposit to CBDC will depend on the conversion possibilities between them. Through a waterfall mechanism an incoming payment that exceeds a threshold could be automatically transferred into the payee's bank account, becoming a bank deposit. A reverse waterfall allows a payer to make a CBDC payment that exceeds the holding to immediately draw from payer bank account. This option to allow easy conversion from CBDC holding to bank account a vice versa could, as contrary as usually thought, to increase bank deposit instead decreasing them. This cannot be said in case of a financial crisis. Due that it's a direct liability of the central bank is considered a really safe asset, therefore an easy conversion as the reverse waterfall one could lead to uncontrolled bank runs. This as previously stated can hinder monetary policies implementation and lead to a snowball effect for a starting financial crisis.
3) Chiu et al (2019, 2022) state that an appropriate CBDC interest rate could increase bank lending and investment by making deposit market more competitive

[90] Auer, R., Cornelli, G., & Frost, J. (2020); Auer, S., et al., *CBDC and the Banking System*, Questioni di Economia e Finanza (Occasional Papers), No 829, 2024.

[91] Chiu, J., & Davoodalhosseini, M., *Central Bank Digital Currency and Banking: Macroeconomic Benefits of a Cash-Like Design*, Staff Working Paper, No. 2021-63. Bank of Canada, 2021.

4) Chiu and Davoodalhosseini (2021) also state that an interest bearing CBDC could increase demand for goods from users that will receive interest payments on their CBDC. Consequently, this can increase the demand for loans for finance the production of goods.
5) In case of a bank failure can provide a parachute for payment system ensuring an alternative for digital deposits (Williamson 2022). Moreover, in case of a bank run (either fostered or not by CBDC) withdrawals in CBDC can be easier to observe and help policy makers to better manage the disarray (Keister and Monnet 2022; Priazhkina 2022)[92]
6) Foster innovation and competitivity. As said commercial banks will have to update their business models, innovate bank deposit features to adapt toward a new global mean of payment. Domestic retail CBDC will be just the start. Retail CBDC are possibly on the verge to a new era of multicurrency cross-border payments to an instant, disintermediated payment with a reduced settlement risk (see Auer, Haehne and Holden 2021; IMF 2024). Wholesale CBDC are also on the track with various project, BIS mBridge project (2023) on the forefront.[93]

1.5.3.1 Risks

As said CBDC can lead to potential risks for economies and financial systems. Commercial banks are not exempted from that, potentially accusing the largest share of risk.

1) Potential decrease in deposits:

   This effect has variables. Agur et al. (2021) points out that if banks have no market power CBDC introduction may lead to a decrease in deposits, increase in lending rates and a contraction in bank lending. CBDC could also limit banks market power reducing their profits and increase banks deposits and lending (see above)

[92]Williamson, S., *Central Bank Digital Currency: Welfare and Policy Implications*, Journal of Political Economy, University of Chicago Press, 130(11), 2829-2861, 2022; Keister, T., & Monnet, C., *Central Bank Digital Currency: Stability and Information*, Journal of Economic Dynamics and Control, Elsevier, 142(C), 2022; Garratt, R., & Priazhkina, S., *Regulatory Requirements of Banks and Arbitrage in the Post-Crisis Federal Funds Market*, Staff Working Papers, No. 22-48. Bank of Canada, 2022.

[93]Auer, R., Haene, P., & Holden, H., *Multi-CBDC Arrangements and the Future of Cross-Border Payments*, BIS Papers, No. 115, March, 2021 Reslow, A., Soderberg, G., & Tsuda, N. *Cross-Border Payments with Retail Central Bank Digital Currencies: Design and Policy Considerations*, IMF Fintech Notes, 2024.

2) CBDC remuneration:

   The impact already mentioned on bank deposits will also depend on CBDC holding remuneration. If higher than bank deposits, people might rather prefer to hold CBDC regardless they would use CBDC for payments. This is one of the reasons why CBs prefer a no remuneration CBDC. However, during times of negative interest rates on deposits, there's still might be a turning to CBDC. Taking digital euro proposals as example, a 3000 euro deposit cap with zero remuneration, with a theoretical -0,5% policy rate (like ECB one between 2019 and 2022) would mean only a 15 euro avoided loss at year per person.[94]

3) CBDC holding limit:

   Without a CBDC holding limit, even in the case of a zero remuneration, if the interest rates are to turn negative there would be a shift toward CBDC by non-financial corporation. ECB proposed to put a 3000-4000 euro limit for individuals and zero holding limit to business users. This doesn't mean they can accumulate holdings but they can make large specific payments, through the waterfall and reverse waterfall functionalities cited above.[95]

4) Stability of deposit funding for banks, credit unions and caisses populaires, which could reduce the liquidity and increase lending costs. This could lead to a loss of stable funding. Seek for external fundings also from non-central banks, and non-secure fundings (BoI 2024). Increased in times of financial instability, leading to more instability. Monnet et al (2020) observe that banks might alter their funding strategies through changing the structure of their assets and pass the gains to deposit holders.[96]

5) Increased deposit rates and funding costs:

   If an interest-bearing CBDC is issued, commercial banks would have to increase their interest rate on deposits to prevent depositors switching toward CBDC. This would increase funding costs for banks. However, if CBDC will ameliorate payment efficiency banks could offset this the increase in funding costs and the decrease in investment (Keister and Sanches 2019, 2022) In a perfectly competitive market they would have to increase interest rates on loans, while in an imperfect competitive

[94] Caccia, E., Tapking, J., & Vlassopoulos, T., *Central bank digital currency and monetary policy implementation*. ECB Occasional Paper Series, No. 345, 2023.

[95] *Ibidem pp.*13-14; ECB (2023) op. cit. p.12.

[96] Monnet, C., Petursdottir, A., & Rojas-Breu, M. (2020). *Central bank account for all: efficiency and stability*. Mimeo

market banks can use buffers to offset the increase in the cost of funds (Chiu et al 2019).[97]

6) Risk of bank runs in time of distress:

   "Digital" bank runs from commercial bank personal accounts toward central bank accounts, undermining financial stability, resulting in a liquidity reduction and a consequent increase cost for bank loans. Further run toward CBDC in times of financial distress, being considered a very safe liability. The easiness in convertibility could lead to an inefficiency in traditional measure to control bank runs, such as bank emergency lending/lending of last resort, i.e. the providing of emergency liquidity in form of loans to prevent the failure of the financial institution, could lead to wider economic problems.[98] Some authors (Keister and Monnet 2019) state that CBDC could be a resource because a CB could easily track whenever there's a bank run. Fernández-Villaverde et al. (2021) state that CBs holding CBDC account may not have the expertise to invest these assets productively, hence lending it to investment banks. This would balance resource allocations as if there wouldn't be CBDCs, and would make CBDC not "callable", so avoiding the risk of mass withdrawal. However, in order to do so CB would be the sole provider of the deposits and would have the power to invest only in specific project, suffering the pressure of political authorities hence hindering the independence of the CB.[99]

7) Disintermediation risks:

   This risk consists in the potential disruption of the two-tier system in banking, allowing central banks (in case of a direct CBDC architecture) to engage directly with de public for financial transaction and potentially bypassing commercial banks. Holding cap and low to zero interest rate on CBDC could discourage users to use it as a reserve value and only as a mean of payment.[100]

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[97] Keister, T., & Sanches, D., *Should central banks issue digital currency?*. Federal Reserve Bank of Philadelphia Working Papers, No. 19-26, 2019; Chiu, J., et al., *Bank Market Power and Central Bank Digital Currency: Theory and Quantitative Assessment*, Chicago Journals, Journal of Political Economy 131 No 5, 2023.

[98] Auer, S., et al., CBDC and the Banking System, Questioni di Economia e Finanza (Occasional Papers), No 829, 2024.

[99] Schilling, L., Fernández-Villaverde, J., & Uhlig, H., *Central Bank Digital Currency: When Price and Bank Stability Collide*. *NBER Working Papers*, No. 28237, 2020.

[100] Auer, S., et al. (2024).

Disintermediation for cross-border/cross-currency settlements/bank transfers, undermining the current role of commercial banks and financial services institutions. The latter such as SWIFT is taking into consideration this possibility and taking fore-measures.[101]

8) Liquidity risk:

   Banks have different levels of liquidity, and may fall below the LCR (liquidity coverage ratio) in result of bank deposits converted in CBDC. This might imply stricter constraints for holdings transition in CBDC. Changes in maturity transformation, increased funding costs and potential decrease in deposits can put banks at ulterior risk.[102]

9) Find new interest rate hedges:

   BoI notice that since many retail deposits are non-maturing deposits (NMD), a decrease in such a natural hedge for value fluctuation of fixed-rate assets when interest rate variates. NMD, holding a relatively fixed cost, helps offset the potential loss in asset value or opportunity costs when market interest rates change. Banking sector might need to find external hedges like interest rate swaps to protect themselves.[103]

10) Potential decrease in payment fees revenue:

    BoI states that 3% of total revenue of Italian banks is related to fees of payment services. Depending on the architecture the banking sector may witness a decrease in its traditional role, or to a variation in the revenue from fees, since CDBC are designed to be low cost if not free to use.[104]

1.5.3.2 Balance Sheet adaptation

This small paragraph is apt to clarify some basic accounting adaptation that must be implemented if CBDC are issued. ECB and BoI underline that both CBs, banking sector and non-banking sector would have to adapt their balance sheet (BS). Without delving too deep in this matter I will quote the most important adaptations needed not to put these stakeholders at

[101] https://www.swift.com/news-events/press-releases/swift-sets-industry-seamless-introduction-cbdcs-cross-border-transactions-interlinking-solution-finds-more-use-cases

[102] Auer, S., et al. (2024).; Auer, R., Frost, J., et al. (2021).

[103] Auer, S., et al. (2024) op. cit. pp. 22-23.

[104] *Ivi* p.25

risk. Non-banks would have an asset shift toward CBDC, with a reduction of cash/banknotes, reversely CB would present a liability swap. The banking sector would be unaffected in this case.

In the case non-banks will convert deposits into CBDC, CB will have to provide liquidity otherwise would lose reserves held by the banks with the central bank (liability swap with declining reserves and increasing CBDC). Banking sector would have to replace its shortening of balance sheet due to a decline of reserves and of deposits with market funding like issuing new bonds, that should however be purchased by non-banks using CB money.

In this frame is very important that the CB lengthen its BS, like increasing its assets purchasing government bonds, in order to provide credit or financial assets to the banking sector otherwise the banking sector would reduce its reserves. Furthermore, could purchase more financial assets from the non-banking sector and the banking sector. In the first case would lengthen the balance sheets of both the central bank and the banking sector given that the financial assets held by the central bank, bank deposits of the non-banking sector and reserves of the baking sector would increase. In the second case would lengthen the central bank's balance sheet and result in an asset swap on the balance sheet of the banking sector with some unencumbered eligible assets (UEA) being replaced by new reserves.

The decline in reserve can lead to the necessity of actions in the monetary policy in order to provide additional reserves as we cited earlier. Moreover, CB should put a limit on the amount of CBDC circulation in order not to put in danger the economy.

$$DL \leq R_0 - R_{min} + (1-h) \cdot UBE_0 - (A_0 - A_{min})$$

Figure 14 Source: European Central Bank (ECB), A Stocktake on the Digital Euro: Summary Report on the Investigation Phase and Outlook on the Next Phase, 2023.

This formula represents on the right side of the equation the amount of additional reserves that a CB can add to its BS from a monetary policy implementation. On the left side of the equation there's the DL which is the bank deposit losses. This constraint ensures that the banking system remain stable as long as the decrease in bank deposit is minor or equal to the increase in reserves.

R0 is the reserves of the banking sector held with the central bank

Rmin is the minimum level of reserves the CB needs to maintain

(1-*h*).UBE0 is the unencumbered eligible assets convertible in new reserves minus the haircut applied to those assets

(A0-Amin) are financial assets eligible for central bank operations. CB is willing to reduce its financial assets to the amount Amin in which Amin<A0. This way the DL is constrained to the Amin amount.

If some of the assets offloaded by the CB were obtained by the banking sector, these could be used as additional collateral for CB credit, thus increasing the amount of DL tolerated.[105]

For further specifications consult the 2023 ECB paper p.22, in which the analysis is deepened with more assumptions and variables that can vary over time.

Bank of Italy shows the potential changes that banking system might confront to cope with the aforementioned potential risks. The assumption develops from the decrease in bank deposits, thus losing a part of reliable source of funding. First of all banks can raise funds increasing short term liabilities, however in the absence of a balancing in the assets side it would result in a deterioration of the NSFR.

Banking sector could increase long-term liabilities. This while keeping BS unchanged would probably increase asset encumbrance as guarantee for the newly issued bonds from the CB.[106]

Banks could reduce their short-term assets reducing their balance sheet. This would worsen the liquidity position, NSFR, asset encumbrance increase. A decrease in long-term assets would reduce the BS but increase the NSFR. Effects on liquidity may vary, if the selloff would be of government bonds liquidity ratio worsen, if sells long term loans to private nonfinancial borrowers liquidity ratio may improve. Depending on the retail deposit outflow banks can opt for various solutions. If the outflow is less than 5% banks can reduce their LCR and NSFR to the regulatory limit, offsetting the reduction in a reduction of excess reserves. In case of an outflow up to 40% more banks would turn to interbank funding. Some banks won't be able to comply with LCR requirements and risk with medium-term unsecured loan to reach the LCR minimum again.

CBDC effect on the banking sector and the market in general will ultimately depend on the take-up (less than 15% of banks' total assets, BoI 2024), use entity, quantitative holding limit, the possibility to invest in CBDC receiving remuneration through holding, the new roles that the banking sector will have in the payment system.

[105] ECB (2023) op. cit. pp.19-23.

[106] Auer, S., et al. (2024) op. cit. pp.21-23.

1.5.4 End Users

Under End Users umbrella we find all potential beneficiaries of CBDC: consumers, households, businesses and merchants.

1) Payment features:
   - Regardless the architecture and infrastructure, CBDC – conformingly to BIS indications – has to ensure seamless 24/7, instant, online and offline, low to no cost payments accepted everywhere and convertible with other types of money like cash and private money.
   - CBDC should promote financial inclusion to people in developing countries, unbanked and those unable to reach bank branches.
   - International B2B payments are envisioned also for retail CBDC, possibly in a multicurrency standardized platform to a faster, cheaper process.
   - In this globalized framework paying cross-border remittances between households could be a flawless solution for many families.
   - Facilitated tax payments. As for governments that could decrease tax evasion and increase tax revenue, general public could enjoy a streamlined – for now conjectural - tax payments system.
2) System features:
   - As the major concern for the general public results to be privacy, CBDC infrastructure and technology ensure users personal data either not gathering it in the first instance, deleting it after a period of time or encrypting them under pseudonym. Protection from cyber-attacks is also of utmost importance, in order to keep data safe and the system resilient with no disruption.

     The topic is still partial and will surely need further research.
   - As we said, the system has to be scalable and interoperable in order to ensure high throughput even with other private sector's payment systems with potentially higher volumes in the future.
   - System has to be resilient also during natural disasters or societal disruption - such as during covid - ensuring citizens direct, instant and aimed financial aid toward whom is incapable of moving. This feature translates also to specific contribution toward low-income households which would use CBDC to purchase basic necessities (for reference see above *Sections 1.1, 1.3.2, 1.3.2.2, 1.5.1.3*)

A CFA institute global survey on CBDC, reported that 42% of respondents think that CBs should issue CBDCs, 34% disagreed and 24% expressed no opinion. It must be taken into account that only 13% of the more than 4000 respondents had a strong understanding of what CBDC is.[107] As said regarding governments, general public has the right to clearly be informed regarding CBDC, most importantly CBDC privacy and security features through multiple media. Politics should refrain to interfere with demagogical deception.

The key to CBDC successful take-up will depend on people trust and acceptance. The latter, for Vu Minh Ngo et al. (2023) will depend on government performance, inflation rate, economic inequality and technological literacy. Sun (2019) states that sharing knowledge through various media on CBDC features, security and privacy concerns can steer up CBDC acceptance and adoption.[108]

1.5.5 Technology and Payment Services Providers:

These key stakeholders will address to shape efficiency, security and functionality of CBDC. This will surely depend on the design, architecture, legal framework chosen. Existing platforms and channels can be used, in order to ensure the detected core features.

1) Technology Providers:
   - Ledger design: As analyzed in *Section 1.3.2.1*, conventional or DLT ledger will address the role of such intermediaries in record keeping - for what concern what and how much data is stored and by whom - and ultimately in the settlement, if PvP will be implemented to face counterparty risk.
   - Digital Wallets and User Interfaces: For the general public to access and use CBDCs, intuitive and secure digital wallets are essential. Technology providers are responsible for designing these wallets, which must integrate seamlessly with existing financial systems while offering user-friendly experiences, together with an offline feature. This will, as well as governmental promotion, ease the public's take-up and usage. [109]

[107] Deane, S., & Fines, O., *CFA Institute Global Survey on Central Bank Digital Currencies*, 2023.

[108] Ngo, V. M., et al., *Governance and Monetary Policy Impacts on Public Acceptance of CBDC Adoption*, 2022, pp 85-94.

[109] BIS (2020) "Foundational Principle"; Kahn, C. M., Rivadeneyra, F., & Wong, T.-N., *Should the central bank issue e-money?* Bank of Canada Staff Working Paper 2018-58, 2018; Carapella, F., & Flemming, J., *Central*

2) Payment Service Providers:

Payment service providers (PSPs) play a critical role in the distribution and use of CBDCs. These entities, which include fintech companies, traditional banks and mobile payment platforms, act as intermediaries between the central bank and the end-users of the CBDC.

- Integration with Existing Payment Systems: In a two-tier system CBDC will be a liability of the PSPs. They will also ensure that CBDCs are compatible with existing payment infrastructures. This includes integrating CBDCs with point-of-sale systems, online payment gateways, and cross-border payment networks. Programmable money related payments. PSPs facilitate the smooth transition from traditional forms of payment to digital currencies, minimizing disruption for consumers and businesses. This will comply with CBDC core payment and feature requirements, as well as its validity as a legal tender.
- In a two-tier system PSPs will not be outshined by CBDC. On the contrary, will burden to fulfill AML/CFT and KYC requirements. CBs and PSPs will have to clearly draw responsibilities and state how to carry on those requirements.

CBDC will foster innovation, technological advancement and competitivity. Countries that successfully integrate technology providers and PSPs into their CBDC strategies may gain a competitive edge in the global financial system. By leveraging cutting-edge technology and efficient payment systems, these countries could position themselves as leaders in digital finance, attracting investment and fostering economic growth.

While technology providers and PSPs offer significant benefits in the implementation of CBDCs, their involvement also presents several challenges and risks.

1) Data Privacy and Security Concerns: The digitization of currency raises critical issues around data privacy and security. With PSPs and technology providers handling vast amounts of sensitive financial data, there is a risk of data breaches, unauthorized access, and misuse of personal information. Ensuring that these entities adhere to strict data protection regulations and implement robust security measures is essential to maintaining public trust in CBDCs.
2) Systemic Risk: The integration of CBDCs into the financial system could introduce new systemic risks, particularly if large PSPs or technology providers fail. As a central node, if a significant cybersecurity breach or technical failure in a major PSP could

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bank digital currency: a literature review, FEDS Notes, Washington: Board of Governors of the Federal Reserve System, 2020.

disrupt the entire CBDC ecosystem, leading to a loss of confidence and potential financial instability. Central banks and regulators must establish clear frameworks to mitigate these risks, including contingency plans and oversight mechanisms.

3) Competition and Market Dynamics: The involvement of PSPs in the CBDC ecosystem could alter market dynamics, potentially leading to increased competition among payment providers. While competition can drive innovation and lower costs, it could also result in market concentration if a few large PSPs dominate the CBDC space. This concentration could reduce consumer choice and increase the risk of monopolistic practices.
4) CBDC costs: CBs may offset operational costs on PSPs, which would then transpose it to end users, thus potentially hindering willing of adoption, contrary to the inclusive free to low-cost principle. CBs may translate seigniorage profit to cover operational and service costs but the research is still at its early stages. [110]

Technology and payment service providers are indispensable stakeholders in the implementation of CBDC. Their involvement brings numerous benefits, including technological innovation, enhanced financial inclusion, and improved efficiency in payment systems. However, their participation also introduces challenges, such as data privacy concerns, systemic risks, and shifts in market dynamics. As central banks move forward with CBDC initiatives, they must work closely with these stakeholders to harness their expertise while mitigating potential risks. By doing so, they can ensure that CBDCs are implemented in a way that promotes financial stability, economic growth, and broader societal benefits.

1.5.6 International Organizations:

IMF, World Bank and other regional bodies will help in guiding Countries to convey what could be country specific regulation to possibly international standards, envisioning a Global openness to exchange CBDC not only for cross border multi-currency retailing but also for

[110] BIS (2020) “Foundational Principles”; Auer, R., Cornelli, G., Frost, J. (2021).

wholesale disintermediated CBs settlements. The risk is the same as for CB and commercial banks, i.e. creating financial imbalances with global reverberance.[111]

The Atlantic Council with its GeoEconomic center has been greatly active on CBDCs research. The tracker has been of great help for the purposes of this thesis providing an updated map of the overall international situation, with researches made nation by nation. Reports has been made for ongoing projects either national, wholesale or retail, and cross-border between different CBs.[112]

BIS takes into account CPMI (2020) opinion about G20 roadmap to enhance cross-border payments through CBDC to ameliorate cross-border payments. CBs should think on an international dimension while designing CBDC to ensure interoperability between different currencies, to create a new generation of payment method in a stable financial system. If not will be just a protraction of the current fragmentation.[113] FSB 2023 report on G20 roadmap concedes the last paragraph to researches on CBDC cross-border payments carried on by CPMI, BIS, World bank and IMF in a joint report to the G20. The report says that CBs have now the possibility to design a CBDC *ex novo*, with features that can overcome the current cross-border payments' limitations. For example, as we saw for the core features could be made available 24/7 to overcome the mismatch hours across jurisdictions. They would be safer since they are a direct liability on the central bank (depending on the architecture), and no need for the PSP to act as liquidity provider. They should be interoperable with current payment methods; risks should be carefully considered such as digital dollarization and currency substitution that can hinder monetary policy and financial stability. For what concerns retail CBDC for cross-border payments it entails the possibility for non-residents, e.g. tourists, business travelers, expatriates who want to pay remittances home, resident branches of foreign corporates, to use domestic CBDC either with a domestic CBDC account or a foreign one through a PSP converting the currency.[114]

G7 (2021) also participated to design CBDC principles, in particular for what concerns its purposes of supporting the fulfillment of public policies objectives, complying to the do no

[111] Adrian, T., & Mancini-Griffoli, T., *The rise of digital money*, IMF Fintech Note 19/01, 2019; Bossone, B., Ardic A., Oya P., *Central Bank Digital Currency: Background Technical Note*, Washington, D.C. World Bank Group, 2021.

[112] https://www.atlanticcouncil.org/cbdctracker/; https://www.atlanticcouncil.org/issue/digital-currencies/

[113] Auer, R., Frost, J., Gambacorta, L.et al. (2021) op. cit. p.21.

[114]Financial Stability Board (FSB), *G20 Roadmap for Enhancing Cross-border Payments: Consolidated progress report for 2023*, 2023.

harm to monetary and financial stability, privacy and data safekeeping, data use transparency, operational resilience and cross-border functionality.[115]

The World Economic Forum (2021) published a white paper to analyze the privacy choices available for CBDC, like the e-Krona model and the ECNY one, then individuating three components which composes privacy features: functionality, privacy guarantees and integrity or security requirements.[116]

We can see that International Organizations as stakeholders are in the forefront to help CBs cooperation in CBDC design. Their main objective is improving coordination across jurisdictions, help provide theoretical CBDC foundation with the purpose of domestic payment innovation for an ultimate international synchronization.

In consideration of stakeholder's regard and concern, we know that CBDC interest is more at macroeconomic level. Consumers, merchants and businesses are not openly calling for a CBDC if not for a smooth and inclusive payment system, that they would enjoy if it will meet privacy requirements. Privacy, data safety, monetary policy, financial stability and stability of the banking sector are the main apprehension of each one of the stakeholders taken into account.

[115] Group of Seven (G7), *Public policy principles for retail central bank digital currencies (CBDCs)*, 2021.

[116] World Economic Forum (WEF), *Privacy and confidentiality options for central bank digital currency*. White Paper, 2021.

Chapter 2 – China DC/EP, an analysis

The present chapter will carry an in-depth analysis of E-CNY, consulting the official available information as well as the current literature on the topic. To note that official papers regarding E-CNY are limited, partial and deficient of technicalities. Progress of Research & Development of E-CNY in China is the sole and most consistent PBOC (People's Bank of China) white paper published in 2021, and where possible I will complement its information with related papers.

2.1 Definition and Taxonomy

E-CNY or DC/EP (Digital Currency/Electronic Payment), is the digitalized version of the Chinese domestic fiat currency. Research started in 2014 and in 2017, after the approval of the State Council, the PBOC began working with commercial institutions to test E-CNY. In 2020 started pilot program in some selected cities and province that we will analyze in the third chapter.[117]

E-CNY is reckoned as Currency in Circulation (M0), therefore counted as a physical currency, a direct emission of the central bank reserves. It counted for 13.61 billion yuan in

货币供应量
Money Supply

单位：亿元人民币
Unit:100 Million Yuan

项目 Item	2023.01	2023.02	2023.03	2023.04	2023.05	2023.06	2023.07	2023.08	2023.09	2023.10	2023.11	2023.12
货币和准货币（M2） Money & Quasi-money	2738072.06	2755249.23	2814566.31	2808469.34	2820504.68	2873023.83	2854031.56	2869343.25	2896659.11	2882276.07	2912014.22	2922713.33
货币（M1） Money	655214.16	657938.74	678059.63	669761.55	675252.98	695595.48	677218.92	679588.35	678443.65	674696.07	675903.41	680542.52
流通中货币（M0） Currency in Circulation	114601.30	107602.58	105591.30	105904.46	104756.71	105419.20	106129.68	106515.36	109253.22	108565.35	110225.18	113444.64

注：自2022年12月起，“流通中货币（M0）”含流通中数字人民币。12月末流通中数字人民币余额为136.1亿元。修订后，2022年各月末M1、M2增速无明显变化。修订后“流通中货币（M0）”增速如下：

From December 2022, e-CNY in Circulation is covered in Currency in Circulation. The amount of e-CNY in Circulation at end December 2022 is RMB 13.61 billion. After applying the new method, M1 and M2 growth rates remain unchanged, M0 growth rates in 2022 are updated correspondingly:

	2022.01	2022.02	2022.03	2022.04	2022.05	2022.06	2022.07	2022.08	2022.09	2022.10	2022.11	2022.12
流通中货币（M0）	18.5%	5.8%	10.0%	11.5%	13.5%	13.9%	13.9%	14.3%	13.6%	14.4%	14.1%	15.3%

Table 3 from Bank of China 2023 Money Supply.
Source : http://www.pbc.gov.cn/eportal/fileDir/diaochatongjisi/resource/cms/2024/01/2024011714335887444.pdf

[117] Working Group on E-CNY Research and Development of the People's Bank of China, *Progress of Research & Development of E-CNY in China*, People's Bank of China (PBOC), 2021. Hereinafter cited as White Paper.

the face of the 11.34 trillion yuan of total cash circulation.[118] Fan Yifei, Deputy Governor of the People's Bank of China expressed that positioning E-CNY in M0 allows the currency to function as a legal tender, serve as a medium of exchange and store of value. The state must centralize fiat currencies to maintain control over the monetary systems, in contrast to private or decentralized currencies.[119]

During the Press Briefing on 2022 Financial Statistics, Deputy Governor of the PBOC Xuan Changneng stated they are together because E-CNY nature is essentially the same of physical cash. Is useful to count them together in money supply for statistical, analytical purposes and to conduct coordinated management.[120] Physical RMB and E-CNY will coexist. This new mean of payment will not cancel physical RMB as long as there will be demand for cash.[121] E-CNY circulation is still showing 2022 numbers even though the pilot expanded in numerous provinces. Just for instance, the sole Suzhou counted in total 29 million digital wallet opened, more than 8 million transactions and a total transaction entity that exceeds 5 trillion yuan since the start of the pilot.[122] We will see if the 2024 Financial Statistic release will show an update in such sense.

E-CNY is issued by the PBOC and is operated by Authorized Operators. It's a direct liability of the CB and has the status of legal tender. PBOC is the sole entity with the right to issue E-CNY in a two-tier operational system. Authorized Operators are the commercial banks and commercial institution that meet compliance requirements (AML/CFT) and regulatory requirements. They can participate in E-CNY payment system, exchange and circulate it to the public.[123] China commercial banks count Bank of China (BOC), Industrial Commercial Bank of China (ICBC), Agricultural Bank of China (ABC), China Construction Bank (CCB)(the so called "big four" state-owned commercial banks), BOCOM, Postal Savings Bank of China (PSBC), China Merchants Bank (CMB), China Industrial Bank (CIB). PSPs count Alipay's Zhejiang MyBank Co., Weixin pay's Shenzhen Qianhai Webank Share Limited Company. Telecommunication companies are also counted as authorized operators.

[118] People's Bank of China (PBOC), *Money Supply Report*, January 2024.

[119] Fan, Y., *Analysis of the Policy Implications of the Positioning of e-CNY as M0*, 2022.

[120] http://www.pbc.gov.cn/en/3688247/3688978/3732405/4782603/index.html

[121] White Paper (2021) p.5.

[122] https://jrjgj.suzhou.gov.cn/szdfjr/tpxw/202407/1637fc22ea5e4bb5b0f77b3390fa369e.shtml

[123] White Paper (2021) pp.4-5.

E-CNY is born as a retail CBDC,[124] even though recent multi-currency wholesale pilots such as 2023 mBridge show that E-CNY may and want serve for inter-bank and financial institution settlements.

Alipay, Tenpay, Credit card money and CDBC all represent a form of digital currency. More precisely, the first three are digitalized form of paper currency and private money, a digitalized version of M1 and M2 type of money supply. CBDC and E-CNY are born digital form of public money. So private digital currencies derive from cash or credit, whereas the E-CNY is independent from cash, incarnating instead its digital form. Cryptocurrencies are also a form of digital currency, however not backed, issued or a direct liability of a CB institution.

As a direct expression of digital cash E-CNY is not interest bearing. It will earn interest only in case its stored in an interest-based bank account. E-CNY is not designed as a substitute of cash but to complement it, either most likely it won't substitute M1 and M2 because already highly digitalized form of money (Cai 2023; Jiang & Lucero 2021; Zhang & Wang 2021).[125]

Considering White Paper and Director-General of the Digital Currency Institute at the People's Bank of China Mu Changchun (2022) discussing E-CNY features, it can be said the E-CNY is thoroughly engaged with the 3 Fundamental Principle of do no harm, coexistence with cash and promotion of financial innovation and efficiency. It partially complies with the institutional features. It is fully convertible and bears no cost for users, but being still a pilot is not yet accepted outside the pilot's borders. Moreover, not all merchants within the borders implemented this new payment feature. Exploring the system features we will notice that many technical properties are still not disclosed. However, authorities affirm it to be efficient thanks to its settlement upon payment system. It is secure due to deploying of various technologies such as digital certificate system, digital signature and encrypted storage to cope with illegal activities such as double-spending, illegal duplication, counterfeit, transaction falsification. It is resilient, offering online and offline payments, available 24/7/365, and interoperable between PSP and Commercial banks, ensuring easy portability. Additionally,

[124] *Id.* p.5.

[125]Cai, N., & Jia, S., *Digital Currency and Currency Digitalization: Comments on the Similarities and Differences of DCEP, WeChat Payment, Alipay, Credit Card, and Bitcoin* (*数字货币与货币数字化———兼评数字人民币（ＤＣＥＰ）、微信支付、支付宝、信用卡与比特币的异同*), 2023; Zhang, X., & Wang, T., *What Is the Difference Between Digital Currency, Alipay, and WeChat Pay?* (*数字货币，和支付宝、微信支付有什么区别*), Xinhua Bao Yewang (新华报业网), 2023.

thanks to the "loosely coupled accounts" users can make immediate transfers between E-CNY wallets even without possessing a bank account. The throughput is about 10000 TPS, it's preparing to enhance its scalability either for domestic and cross-border payments, either for Chinese citizens and to non-residents. Its programmable and on the verge to apply smart contracts to its payment features.[126]

2.2 Architecture, Infrastructure, Access Verification

Technical infrastructure still lacks information. White Paper states that E-CNY offers an anonym, cheap, highly portable and efficient system that works on settlement upon payment system.

E-CNY is a two-tier/hybrid architecture CBDC. PBOC is "responsible for issuance and disposal, inter-institution connects and wallet ecosystem management" (p.9 white paper), i.e. a kind of centralized management. Mu emphasized that there are several reasons why E-CNY is following a centralized management: 1) The digital currency remains a liability of the central bank, ensuring its role in currency issuance; 2) It allows the PBOC to maintain its critical functions on monetary policy regulation and transmission mechanisms; 3) To avoid Authorized Operators over issue E-CNY.[127] Borrowing World Bank words through a centralized management of accounts CB provides authentication, then offering PSPs room for maneuver to add functionalities to control or limit CBDC usage.[128] Accordingly, commercial banks with enough strength in capital and technology are selected to provide E-CNY exchange services. PBOC manages the distribution of E-CNY through a quota system, where Authorized Operators open different types of digital wallets to customers based on their identification strength. Authorized Operators provide payment, circulation and development services. PBOC only processes inter-institutional transaction information and doesn't possess personal information. PBOC ensures a market driven performance for operators balancing

[126] White Paper (2021); Mu, C., *Theories and Practice of Exploring China's e-CNY,* 2022.

[127] White Paper (2021) p.9; Mu Changchun (2022) *Id.*

[128] World Bank, *Central Bank Digital Currency: A Payments Perspective*, 2021.

resources allocation, encouraging innovation. PBOC believes that a two-tier system will encourage the public acceptance of E-CNY.[129]

Regarding the access base E-CNY is an account-based quasi account-based and valued based e-wallet. Authorized operators manage the wallets operability and designs as well as the E-CNY authentication. Payments are made through QR code, prepaid cards or NFC. Users don't need to open a bank account in advance.[130]

White Paper and Mu Changchun define the type of wallets based on different dimensions (White Paper; Mu 2021, 2022).

a) Through KYC there are four wallet categories. For each Identification Requirements there are different wallet caps, single/daily/annual transaction, payments, transfer top-up, receive and balance limits. For the "anonym" Category four wallet, under the Personal Information Protection Law (PIPL), telecommunication operators cannot divulge any identity information to the PBOC and/or to any third operator. Providing a valid ID, facial information and bank account users can upgrade to other categories with higher caps on wallets. It must be noted that currently only Chinese ID and Bank Account using Union Pay circuit are Accepted.

Wallet Category and Limits

		Category 1	Category 2	Category 3	Category 4 (Anonymous)
Identification Requirements		- Mobile number - Valid ID - Linking bank account - Visit a bank branch	- Mobile number - Valid ID - Linking bank account	- Mobile Number - Valid ID	- Mobile Number
Wallet caps	Balance	Unlimited	500000	20000	10000
	Single Transaction		50000	5000	2000
	Daily		100000	10000	5000
	Annual		Unlimited	Unlimited	50000

Table 4 Wallet Category and Limits source: E-CNY app.

This will be further analyzed for what concern foreign users using foreign bank accounts in End Users as stakeholders' section. Regarding wallet limits, each Authorized Operator can present some modifications in Payments and Transfers, like for instance Webank (Weixin Pay) for Category two wallet applying a Daily Transfer and Payment limit of 20000 yuan differently from the others.

b) By the type of holder there are individual and corporate/public wallets. Natural persons, self-employed/non-corporate can open the individual wallet, managed by classified transaction and Identity Requirement strength. Legal persons and

[129] White Paper (2021) p.9; Mu, C., *Balancing Privacy and Security: Theory and Practice of the E-CNY's Managed Anonymity*, 2021, p.2

[130] Zhou, X, *China's Choices in Developing Its Digital Currency System*, Caixin Global, 2021; White Paper (2021) p.10.

unincorporated organizations can open the public wallet. Here transaction and balance limits depend whether they opened the wallet in person or in remote, while functions vary suiting different user needs.

c) Considering the carrier type there are software and hardware wallets. Soft wallets can provide payment via APPs or Software development kits. Hardware wallets are supported by IC cards, Mobile phones chips, wearable objects and IoT devices with payment functions.

d) According to the attribution of authority, E-CNY can be classified as main wallet and sub-wallets. Users can set the major wallet as the main one, then open other sub-wallets under the main wallet. Sub-wallets can be used on e-commerce, O2O platforms to insulate personal information and safeguard user privacy. Enterprises and institutions can directly distribute funds through sub-wallets to users.[131]

2.2.1 Technology and Infrastructure

Specificalities on infrastructure and technologies are not public, therefore the research limits itself on the breakdown of the White Paper, the other official papers and the related literature along the lines of the BIS' CBDC ledger characteristics and technological features listed in the first chapter.

Looking at the ledger design, the structure is claimed to be a mixture of decentralized and centralized features. Blockchain technology by DLT ledger is used but without limiting openness to alternative solutions. It's stated to be useful to help reconciliation. White Paper also state E-CNY to lay onto a platform-based design, meaning that the system is easily adaptable to expansions and integrations, in sight of a possible increase of users, transaction numbers and volumes. Moreover, it's claimed to handle a city-level disaster tolerance which allegedly ensures, even in cases of natural disasters or major technical failures, that the system can keep operate. Although this statement, Chapter VIII i.2. of the App User Service Agreement exempt itself from liability in cases of force majeure events such as typhoon,

[131]White Paper (2021) pp.10-11; https://finance.sina.com.cn/meeting/2021-06-11/doc-ikqciyzi9071612.shtml; http://www.pbc.gov.cn/en/3935690/3935759/4749192/2022122913350138868.pdf; Galbraith, A., & Shen, S., *China Central Bank Launches Digital Yuan Wallet Apps for Android, iOS*. *Reuters*, 2022

flood, thunder, terrorist attacks, etc,.[132] Payment authentication appears to be multifactorial. Identity verification is needed to scale up in wallet category while token characteristics like digital certificate system and digital signature are applied. Digital Certificate System, is a cryptographic document used to authenticate the identity of the parties involved in the transaction. Such technology ensures against man-in-the-middle attacks and unauthorized access.[133] Digital signatures serve to allow participants to prove that they have authorized a transaction. Such signature on the transaction is unique and un-alterable. This is useful to prevent unauthorized spending and payment repudiation. Concerning functionalities, Mu Changchun claimed on several occasions[134] that E-CNY infrastructure is open to the use of smart contracts, also remaining open to further innovations. Looking at the access requirements we can infer from the White Paper that E-CNY adopts Encrypted storage, ensureing that sensitive transaction data is protected from unauthorized access or tampering. Transaction amounts, users' identities and transaction histories are protected. AML/CFT operators, as well as PBOC and authorized commercial institutions have access to such data with the duty of safekeep and not disclose them. PBOC is the administrative authority for AML while in the practice is carried by Operators. Multi-layered security system shall ensure E-CNY network security against external attacks, data security either when being at rest or in transit, application security and user authentication. Multi-layered approach guarantees against single point of failure of the system, so that if one layer is compromised the system keeps functioning. For governance requirements there's still not a rulebook such as the one envisioned in the BIS papers.[135]

With respect to the 5 technological features. 1) convenience: its convenience its ensured thanks to QR code payments via NFC and offline payment availability. 2) Security and resilience: the system is claimed to be both. We discussed of the resilience features of DLTs that can count on multi-situated data centers which can ensure uninterrupted services even in case of failure of one center. Mu Changchun pronounced himself at 2024 "Chang'an Street Reading Club" (长安街读书会) on E-CNY infrastructure cryptography measures. It operates following to the "Cryptographic law" operating with the "three simultaneous actions and one

[132] E-CNY APP, App User Service Agreement, consulted last on 4/2024.

[133] https://id4d.worldbank.org/guide/digital-certificates-and-pki

[134] Mu, C., *Smart Contract and E-CNY*. CF40, September 19, 2022.

[135] White paper (2021) pp.8-16; Laband, J., *Existential Threat or Digital Yawn: Evaluating China's Central Bank Digital Currency*. Harvard International Law Journal, 63(2), 14-18, 2022.

assessment" which involves "synchronized planning, construction and operation of the commercial cryptography protection system along with periodic security assessment". The National Financial Cryptography Application Research Center, established in collaboration with universities and government bodies, is promoting cutting-edge cryptographic research and secure applications in digital yuan operation, fostering industry-academia collaboration to enhance digital currency security. 3) Fast and Scalable: As we know at the moment the system can sustain a throughput of 10000 TPS, but its open design suggests that there's great potential for scaling up, granted also to the consistent willing for expansion of the pilot to more provinces each year. 4) Interoperable: the ECNY APP is interoperable with WeChat and Alipay. Binding the ECNY wallet directly to WeChat and Alipay system App, payments and transfers are easily done. 5) Flexible and Adaptable: White Paper and Mu Changchun state that the technological ecosystem is various and open to innovations either in structure and services, granting an environment for continuous development.[136]

Ma Guangqi and Chen Xuemeng outlined the technical components, security features and assurance mechanisms to safeguard and implement E-CNY that are reported in this overview table here below translated.[137]

Security Technology	**Basic Security Technology**	**Encryption**: Encryption on digital currency generation, transmission, identity verification, establishing a complete encryption law system **Security Chip**: Achieving security storage and decryption operation using mobile terminal-based chips	
	Data Safety Technology	**Secure Transmission**: Transmission of digital currency information using encryption + MAC/encryption + HASH methods **Secure Storage**: Secure storage of digital currency information through encryption storage, access control, and security monitoring	
	Transaction Security	**Non-repudiation**: Zero-knowledge nature (including participation signature, weak signature, strong signature, etc.) for digital currency transactions **Identity Authentication**: Verifying the identity of digital currency users through authentication	

[136] White paper (2021); Mu, C., *"Reform and Innovation" Mu Changchun: Using Cryptography as a Cornerstone to Continuously Build a Secure Ecosystem for E-CNY* (*改革创新」穆长春：以密码为基石，持续构建数字人民币生态安全体系*), Tencent Web (腾讯网)， 2024.

[137] Ma, G., & Chen, X., *Research on Operation Mechanism and Expected Effect of E-CNY* (*数字人民币的运行机制和预期效应研究*). *金融发展评论*, 2023(04), 1-13.

	Technology	centers **Double Spending Prevention**: Using digital signatures, traffic marks, timestamps, etc., to ensure digital currency is not used more than once **Anti-counterfeiting Technology**: Using encryption, digital signatures, and identity verification to prevent counterfeiting and ensure the authenticity of digital currency.	**Circulation ability, Storability, Controllable Anonymity, Offline Transactability, Non-counterfeiting, Non-repudiation, Non-repeatable Transactionality**
Transaction Technology **Trusted Assurance Technology**		**Online Transactions**: Ensuring online processing of transactions via interaction between online devices and secure data transmission technology **Offline Transactions**: Enabling offline transaction processing using devices that can interact offline and escape-data transmission technology **Trusted Service Management**: Secure management of digital currency modules and application data using a Trusted Service Management (TSM) platform. Ensures trusted security moules (SE), application lifecycle management, application registration, updates, storage management, security evaluation, and trusted carriers.	

Table 5: E-CNY technical security features. Source: 数字人民币的运行机制和预期效应研究[J].金融发展评论,2023(04):1-13.DOI:10.19895/j.cnki.fdr.2023.04.001. Table 1 表 1 Author's Translation.

All these infrastructural design features are tested on the field of the pilot cities and provinces along with the product stability and usability monitoring results and feedbacks.[138]

2.3 Legal framework and Privacy implications

2.3.1 Legal framework

PBOC has made a draft update on Law of the People's Bank of China that shall come into effect in 2023 (Jiang & Lucero 2021) that ensures E-CNY legal authority. Chapter III Art.19 added from the previous versions that "RMB exists both in physical and digital forms".[139]

PBOC possess the monopoly of issuance of E-CNY. The currency has legal tender status and can be exchanged on a pair with cash within the territory of the pilots. The new draft ensures protection under criminal law, complying with the regulations that administrate RMB. National and international laws on AML/CFT apply and will be carried on by authorized

[138] *Id.*; People's Bank of China, *PBC Holds Meeting on Pilot Program of E-CNY R&D*, 2022.

[139] https://www.gov.cn/zhengce/zhengceku/2020-10/24/content_5553847.htm ; Jiang & Lucero (2021).

operators and commercial institutions. They will gather customers' due diligence, identity data and record transactions while protecting such data from leakage or external attack.[140] In cases of financial crime, the impact of freezing an E-CNY wallet remains uncertain. While both the PBOC and intermediaries theoretically have the ability to block or freeze E-CNY wallets, Jiang & Lucero (2021) points out that the consequences for citizens are unclear. Unlike an Alipay account, where a new account can be opened if another is frozen, E-CNY is identity-based, making the process less straightforward. Authorities should provide clearer regulations regarding blocked accounts and the handling of E-CNY within them. Authors also notes that the PBOC will be responsible for compensating fraud victims, reversing transactions, and investigating the fraud.[141]

Sun (2021) observes that the literature doesn't agree completely on the legal tender status of E-CNY. The unlimited payment ability that should characterize it's limited by E-CNY technical characteristics itself. Technical infrastructure failures can undermine payments, thus invalidating the universality status required for a legal tender. Moreover, both parties shall possess electronic accounts, another intrinsic limitation. Be that as it may, it must be noted that in some cases the pilot is implementing solutions to remedy this problem. Qingdao Subway system is implementing for one line the possibility to use NFC and the Hard Wallet (like a physical card) to enter the metro without the need of internet connection nor power on the phone.[142]

Literature also argues that from Art. 19 all subsequent Articles regarding RMB are then applicable also for E-CNY, but this can lead to inconsistencies and incomprehension, that's why, as White Paper also states, E-CNY should possess proper *ad-hoc* regulation. For instance, "digital form" (数字形式), as stated in the Art.19, doesn't really discern the "legal digital currency" (法定数字货币) from the already existing "digital currencies, virtual currencies, electronic currencies" （数字货币、虚拟货币、电子货币）, whereas, as discussed above, their difference is substantial.[143]

[140] Jiang & Lucero (2021); White paper (2021) pp.10-12.

[141] Aysan, A. F., & Kayani, F. N., *China's Transition to a Digital Currency: Does It Threaten Dollarization? Asia & Global Economy*, 2(1), 1-3, 2022.

[142] http://qingdao.pbc.gov.cn/qingdao/126141/5116940/index.html

[143] Sun, J., *DCEP's Legal Nature* (*DCEP 的法律性质厘定*), 2021, pp.2-6

E-CNY can be inserted into the intangible assets' property rights, that are assured by the control over the object (tangible or intangible), to which it can be exerted a control by individuals and has value.[144]

E-CNY although possessing legal tender status it still needs specifications. In order to be a long-term solution it needs to possess its own regulations, stated and enforced by the PBOC regarding issuance, rights and obligations of each entity, circulation model clarifications, property rights details, enhance and ensure personal information protection.[145]

2.3.2 Privacy implications

On the White Paper is written that E-CNY follows the "managed anonymity" i.e. "anonymity for small value and traceable for high value". Anonymous transaction limits can be identified in the single transaction limit of CNY 2000 for category four (anonymous) wallet. However, *de facto*, the PBOC and consequently the government (tax authorities and law enforcement authorities *in primis*) can have direct access over users' economic activities, possibly flowing into violation of property rights. As stated above, state authorities, authorized authorities and commercial institutions are due to AML/CFT measures, thus gathering large quantity of information from customers like identity data, transactions records, large transaction records and due diligence, clearly with the prohibition of divulgence. Such great amount of data spread also onto health information, consumption habits and behaviors. This stem concerns regarding the centralization of authority by the PBOC, the resulting impacts on freedom of choice, state surveillance for its users, and concerns on the vulnerability of the data.[146]

[144] *Id.* pp. 6-7.

[145] *Id.* pp. 8-11.

[146] White paper (2021) pp.8-11; Sun, J., (2021) op.cit. p.8; Atlantic Council, *Practice Makes Perfect: What China Wants from Its Digital Currency in 2023*, 2023; Mu C. (2022O op. cit. p.7; Mu, C., *Balancing Privacy and Security: Theory and Practice of the E-CNY's Managed Anonymity*, 2021 p.4.

Personal information exchange between wallets during transactions are anonym for what concerns uninvolved third-party intermediaries like commercial banks and internet platform. Between wallets ID anonymization technology is used.[147]

Jiang & Lucero (2021) notice that there are rules controlling government agencies' access to information and the disclosure like the Notice of the State Council on Issuing the Interim Measures for the Administration of Sharing of Government Information Resources and the Guidelines for the Preparation of Catalogues of Government Information Resources, respectively named by the authors in the "Measures" and the "Guidelines".[148] However, their applicability to E-CNY is unclear, because doesn't clearly state what is actually sharable or not, probably also due to the unclear nature of E-CNY and the consequent difficulty of classification. Data Security Law (DLS) and Personal Information Protection Law (PIPL) delimit on how the state can collect, utilize and analyze data.[149] PIPL states that third party information processors require personal consent to obtain information and what information they will process. The third-party will obtain anonymized information and cannot use other technology to re-identify individuals. When gathering sensible personal and financial information they must demonstrate necessity of the collection and obtain the consent. Jiang & Lucero note that it's unclear if these clauses can be exerted for E-CNY and/or in E-CNY App stored personal information, for now it's only detailed on a future tense (Personal Information Protection Policy, PIPP, VI.2.: *we will establish information security guarantee policies and take technical and other necessary measures to ensure your personal information security as mandated by applicable laws, regulations and standards such as the Civil Code, Personal Information Protection Law, Cybersecurity Law and Cryptography Law*).[150] Additionally, individuals and businesses cannot verify if government agencies comply with these laws. To address this Authors suggests that PBOC should implement clear rules release regular public transparency reports.[151]

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[147] Duan, X., *Observation: How Will Central Bank Digital Currencies Affect Us?* (*觀察|央行數字貨幣將如何影響你我*), 2022.

[148] https://lawinfochina.com/display.aspx?id=27873&lib=law; https://law.yale.edu/sites/default/files/area/center/china/2022-9-5_jph_rev_ogir.pdf

[149] Personal Information Protection Law (*中华人民共和国个人信息保护法*), Aug. 20, 2021, effective Nov. 1, 2021 https://personalinformationprotectionlaw.com/

[150] Jiang & Lucero (2021); App PIPP Personal Information Protection Policy, last consulted 4/2024

[151] Jiang & Lucero (2021) *Id.*

APP Personal Information Protection Policy (PIPP), approved in June 2023, explain how information is collected, stored and disclosed. Since the pilots are limited to some cities and provinces, they need to access the location information (I) to ascertain user is inside a pilot's territory. Regarding how to secure App account, wallet, personal and property security (I.ii.) against security risks, App's system and Authorized Operators will record users device information: *International Mobile Equipment Identity (IMEI), Media Access Control (MAC), device location information, Identifier For Vendor (IDFC), Universally Unique Identifier (UUID), device serial number, Android_ID, equipment model etc.; network information like IP address, Wi-fi information, Internet access type, base station ID […]; […]information regarding using of the App including version number, time and frequency at which buttons are clicked, values of some key configurations and software crash logs.*[152] To use E-CNY App, open an account and make payments, you will have to accept App's Terms of Use in total. On how personal information are stored (II), it's said that information is kept inside the Country, it might be shared out only in the case of cross border businesses, after carrying out the security assessment in accordance with laws, provisions and administrative regulations. The user will be informed that the information is transmitted out of China, what information is transmitted, who is the recipient, and what's their data security capability. They will also ensure that the recipient(s) will not divulge such information.

All information will be kept *for the shortest time period necessary for fulfilling the purposes described in this policy (II),* so potentially till the moment of closing the account. In case of account closing or consent withdrawn all personal information gathered will be deleted or anonymized (in case of technical unfeasibility of delete) within 15 working days (II).

On how they use personal information (III). To fulfill requirements for safety (1,2), to report to authorities according to applicable laws and regulations (3), to help them understand how users use the Product (App) (4), for anonymized statistical analysis (5), and other purposes (6), only after asking of further consent.

PIPP (VI.7.) informs that they will conduct security audit and operation monitoring on server systems in which personal information are stored, updating servers operating systems affected with problems. They will train the staff on PIPL on regular basis to raise staff awareness. PBOC has a "firewall" in which personnel is responsible for "information security and privacy protection through institutional arrangements […] for maintenance, business

[152] App PIPP I.ii, consulted last 4/2024.

isolation, hierarchical authorization. Post checks and balances and internal audit" (8). So, both PBOC and authorized operators will be responsible for personal information protection and management. "Information relating to E-CNY will be sealed and stored and all customer information will be de-identified. Without legal authorization, neither PBOC's internal personnel nor any external business unit or individual may inquire or use it at will". Those responsible for unauthorized inquiry will be investigated according to law and held accountable.[153]

For what concerns minors, PIPP (VIII.) refers to Children's Personal Information Protection Policy (CPIPP). The product can be used only under consent and supervision of the "guardian", allegedly a parent, a relative or a tutor. CPIPP is specifically drafted for minors under the age of 14. The guardian will be responsible and give the consent on behalf of the minor.

In case of modifications or amendments of the policy (XI) they will be notified to the user, and in case of not consent to the new Policies, the *user is entitled to opt out of the relevant services.* Modifications can regard the way purposes of gathering personal information (1), control right after change of ownership such after M&A (2), changes on whom they share the information to (3), rights of participating in personal information processing or the method with which this right is exercised (4) […].

Jiang & Lucero observe that part of the regulation concerning what data, the amount and how Government and banks can share and store those data is contained in Chinese Civil Code Artt. 1034 and 1035. The first states that personal information regarding natural persons and that can identify a person separately or in combination with other information are protected by law. E-CNY should be comprised in such protection. Artt. 1035 and 1039 regard the principles and conditions of processing personal information, and the duties of privacy safeguard of users by the entities entitled to manage such data. In this case PBOC is responsible to safekeep users' personal information and activities data. The authors note that however the Civil Code doesn't specify which government agencies will oversee and enforce this law, and how people can check whether their rights are protected.[154]

[153] Mu, C., *Balancing Privacy and Security: Theory and Practice of the E-CNY's Managed Anonymity*, 2021 p.3.

[154] Jiang & Lucero (2021) *id.*

Ultimately Jiang & Lucero note that the rules are ambiguous just as the language used because in case of person refusal, personal information processor can still access data for "public opinion oversight in the public interest". [155]

They underline that the more technical details are disclosed the more potential hackers can come in the way to counterfeit the currency or to undermine Chinese financial system or access people digital money or data.[156]

2.3 Stakeholders

Following the lines traced in the first chapter, we will now delve into each stakeholder's motivation and risk for E-CNY pilot. We already know that some motivations converge for different stakeholders, like CBs, Commercial Banks and Government. International Organizations help in overall theoretical matters, in sight of globalizing achievements. From design choices is shaped the relevance and accountability of Technology Provides. The final product is enjoyed by End Users, keystone of the retail CBDC system, the real benefiters of the services, whose acceptance, feedback and trust are fundamental for the success of the project, being the retail project ultimately designed for them.

2.3.1 PBOC

Motivations moving PBOC toward the issuance of CBDC can be listed as follow:

1) Faster and cheaper payments:

   This motivation is arguable concerning Alipay's and WeChat's payment services, already really low to no costs for consumers' small transactions, whereas however WeChat charges 0.6% merchant fee, Alipay 0.55%. Notably Alipay charges a 3% fee for payments above 200 yuan (25,5euro). E-CNY is no cost for consumers and businesses, even for higher transactions as stated in the design paragraph above.[157]

[155] *Id.*

[156] *Id.* pp. 265-267

[157] https://wise.com/en-cn/blog/alipay-fee-international-cards; https://www.oceanpayment.com/blog/19775/

Alipay ranges from 122000 to 200000 with peaks of more than 500000 TPS,[158] WeChat Pay around 244000 TPS,[159] DC/EP sticks to 10000 TPS with a 300000 future goal. However, if not faster for everyday payment, E-CNY is also envisioned as a tool of direct governmental economic subsidy in times of natural disasters, without the need of the intermediation of a Bank or the need of an internet connection. DC/EP ensures resilience even in case of digital disruption of other PSPs.[160] Data for such a tool is still not available, or not published.

Mu Changchun affirms that application of smart contracts in DC/EP system can lower transaction costs for economic activities and business environment in general. For now, E-CNY smart contracts have been applied for government subsidy transfer, retail marketing, and prepaid fund management, envisioning to widen the scale. Subsidy transfers range from fiscal subsidies and scientific research funds that thanks to smart contracts government funds can be monitored more efficiently. For fund settlement can "solve compliance issues with payment transaction processing" while "reducing manual processing errors and risks". In marketing Mu affirms that can be used for consumers in red packet transfers and smart payments, reducing implementation costs, protecting user's rights and improving customer experience. In prepaid fund management smart contracts can prevent misappropriation of funds and achieve a more secure environment for the parties.[161]

Even though this regards cross-border (momentarily) wholesale settlements, Mbridge project seemed to have executed instant interbank wholesale payments with a shortening of the payment chain and a cut of costs by at least 50%.[162]

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[158] https://oceanbase.medium.com/61m-qps-challenge-in-alipay-how-did-we-do-it-3eeadfb0051; https://x.com/Alipay/status/929123909970153472; Ryan, F., et al., *The Role of WeChat Pay and Alipay in DC/EP*. In *The Flipside of China's Central Bank Digital Currency*. Australian Strategic Policy Institute, 2020. pp. 19–22.

[159] https://www.tencentcloud.com/customers/detail/2904

[160] Mu Changchun (2022) *Id.*

[161] Mu, C., *Smart Contract and E-CNY*. CF40, September 19, 2022.

[162] *Mu Changchun: CBDCs mBridge Can Reduce Transaction Costs by At Least 50% (央行数字货币研究所所长穆长春：多边央行数字货币桥的交易成本可以降低至少 50%)*, Sohu (搜狐), 2023; 央行数字货币研究所所长穆长春：Mu, C., *mBridge Project for Cross-Border Payments Can Significantly Shorten the Payment Chain* (*央行数字货币研究所所长穆长春：货币桥跨境支付可大幅缩短支付链路*), Meitian Jingji Xinwen (每天经济新闻), 2024 consulted on 11/9/24.

2) Diversify the form of cash and support financial inclusion:

The proportion of cash in the total amount of money in circulation dropped to 3% at the end of 2023.[163] PBOC wants to ensure direct access to cash while use of cash in retail payments is declining to 7%.[164] In doing so is complying to its mandate in the era of digital economy. This system is willing to make financial services through E-CNY wallet app profile. DE/EP wants to ensure a payment universality just as the one guaranteed from cash, (managed) anonymity just as cash.

Beside the above-mentioned resilience in case of other payment platform disruption, direct payment in case unforeseen events, DC/EP aims to include unbanked people, that counted for 20% of the Chinese adult population in 2017,[165] to seamless financial services while achieving the digitalization process, and also increasing E-CNY App accounts (through banks).[166] Financial inclusion stems from that expanding to elderly with financial aids and ease of adoption, and to non-residents, who could be able, theoretically, to use the App without need to open a Chinese bank account (we will analyze truth and limitation of this statement while investigating the End Users).[167]

3) Boost internal demand and consumption:

This motivation can somehow connect to the direct governmental subsidies. Numerous promotional activities, that we will thoroughly analyze in the third chapter, are ubiquitously focused on promote E-CNY wallet opening and use, and at the same time try to boost internal demand and consumption. Red packets to be used in street markets or in shopping centers, tax bonuses for buying electric vehicles, loans at discounted rate for people and businesses, for totaling in billions of yuan to root E-CNY as a mean of payment but also to relaunch internal consumption.[168]

4) Fight the duopoly/ provide fair competition:

According to Statista the share of mobile internet users using mobile payment in China got to 87% in 2023.[169]

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[163] http://www.pbc.gov.cn/eportal/fileDir/diaochatongjisi/resource/cms/2024/01/2024011714335887444.pdf.

[164] GPR 2024 The Global Payment Report https://offers.worldpayglobal.com/.

[165] https://www.worldbank.org/en/publication/globalfindex

[166] http://www.pbc.gov.cn/en/3935690/3935759/4749192/2022122913350138868.pdf

[167] Mu Changchun (2021 ; 2022) *Id.*

[168] Reuters, *China Uses Digital Yuan to Stimulate Virus-Hit Consumption*, 2022.

[169] https://www.statista.com/statistics/1243879/china-mobile-payment-penetration-rate/ .

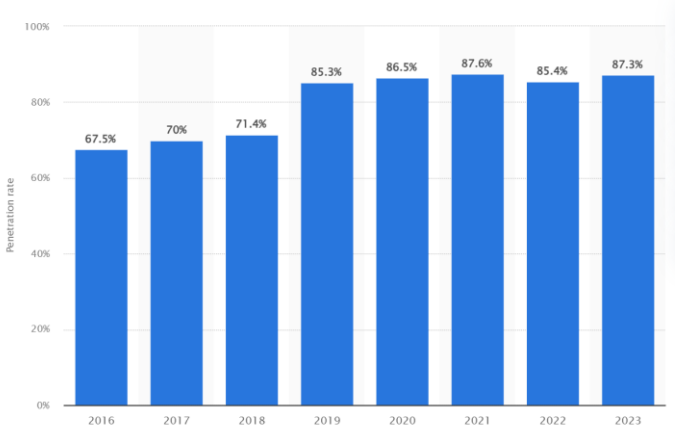

Figure 16 Share of mobile internet users using mobile payment in China. Source: Statista, consulted 09/2024 https://www.statista.com/statistics/1271130/mobile-wallet-user-forecast-in-china/

WeChat and Alipay ha respectively 37% and 55% of mobile payment market share.[170] PBOC might consider that giving such power to a private company is detrimental because disruption of their payment infrastructure could lead to short-term financial risk and instability. PBOC purpose could be either limit their market power and autonomy of these companies, exerting more control on them (Jiang & Lucero 2021).

The White Paper states that E-CNY is meant to support fair competition, efficiency and safety for retail payments, it combines with the current digital payment system while providing additional services such as offline payment. WeChat and Alipay can also carry offline limited payments from account balance but for very limited amount of time and not as an intrinsic feature of the system. Mostly the "fair competition" could be a purpose for E-CNY to be a direct competitor of both, rebalancing powers in mobile payment realm while penetrating in those PSPs making interoperable E-CNY with WeChat and Alipay.[171]

E-CNY features in Alipay and WeChat, beside resulting in a potential depletion of their market share, means more financial data for PBOC. PBOC already forced Tech companies Alibaba and Tencent to share user data like shopping records and travel history to state backed credit agencies Baihang and Pudao, then provided to banks to help assessing borrowers' creditworthiness. PBOC is standing in the way banning online platforms to directly sell user data to banks, for possible misuse of personal information.[172] Favorable E-CNY payment features for consumers and merchants, interoperability with those platforms can reduce market share of these two giants, already pushed to loosen their user payment data monopoly.

5) Maintain currency sovereignty against cryptocurrencies:

[170] https://www.statista.com/statistics/1271130/mobile-wallet-user-forecast-in-china/

[171] White Paper (2021) *Id.*

[172] Yu, S., *China's Central Bank Struggles to Force Tech Groups to Share User Data with State*, Financial Times, 2022. Consulted on 12/9/2024

As also stated in the first chapter. White Paper underlines that Crypto and stablecoins can undermine "financial stability, domestic currency sovereignty [and] serve as an instrument for money-laundering activities."[173] Officially crypto mining and trading has been banned from China since 2021 however Chen & Liu (2022) argue on the effectiveness of the measures, affirming that traders simply use Tether instead of Yuan.[174] E-CNY is wanted to rise as an alternative, safe, state backed, liquid solution to the highly instable, illegal, ML/TF cryptocurrencies.

6) Internationalization of the RMB:

Beside the domestic retail activities, DC/EP possesses an internationalizing proposition of its example and of the RMB adoption for cross-border payments.[175] RMB is the third largest currency in terms of pricing, settlement and international reserves, fifth most active currency for global payments by value.[176] Cross-border digital currency settlement would need international standardized regulations. mBridge is an ongoing project for wholesale cross-border multi-CBDC settlements that we cited various times during this thesis. Its system works in a uniformed platform in which users, mostly central and commercial banks, engage in peer-to-peer payments that respond on the PvP principle. 2022 Report shows a total of 164 payments for over 22million dollars in six weeks between Hong Kong monetary authority, Bank of Thailand, Digital Currency Institute of PBOC and the Central Bank of United Arab Emirates.[177] Other projects regard e-CNY between Hong Kong Monetary Authority, Mainland China and Macau for cross border transactions (2022) and the already cited Project Aurum.[178]

Pettis (2022) observes however that in order to make RMB the top international currency it would need to reshape international trade and capital flows. This means dethroning the dollar, a solution that U.S. is not willing to accept. On top of that, China

[173] White Paper (2021) op. cit. p.3.

[174] Ranganathan, V., & Zhen, S., *Bruised by Stock Market, Chinese Rush into Banned Bitcoin*. Reuters, 2024. Consulted 12/9/24; Chen, C., & Liu, L., *How Effective Is China's Cryptocurrency Trading Ban?*. *Finance Research Letters*, 46(Part B), 2022.

[175] White Paper (2021) op. cit. p.6.

[176] Jia, C., *E-CNY Certain to Promote Renminbi's Internalization*, China Daily Global Edition, 2021.

[177] https://www.bis.org/press/p221026.htm

[178] https://www.atlanticcouncil.org/cbdctracker/

is benefiting from the present situation sending their excess savings generated from trade surpluses to purchase U.S. assets.[179]

Bencivelli & Zangrandi (2023) detect that in order to make RMB the international reserve currency it would need an ease in capital controls, liberalization of financial markets and an improvement of governance transparency. In addition, foreign holding of RMB assets remain limited to 3-4% of whole economy assets. Authors argue that E-CNY technological infrastructure can be shared to other countries' CB being in the forefront for a possible new chapter of digital finance, still a long and rough journey, in which geopolitical acceptance and soft power can play a major role. E-CNY would need to improve its services for foreigners, it should open to use even out of the national borders for Chinese citizens, in the payment of remittances for instance, and ultimately being clear on the data accessible by the government, already a concern in U.S. Senate for its own citizens.[180]

7) More control of the PBOC:

   As previously mentioned, the PBOC is actively seeking more detailed transaction data from platforms like Alipay and WeChat Pay. NetsUnion, a major clearing corporation responsible for processing most digital payments on these platforms, is largely privately owned, which complicates government access to this data (Jiang 2021). With the introduction of the E-CNY, the government could potentially gain significantly more access to consumer data, as noted in Section 2.3.2. Additionally, the PBOC is responsible to implement regulations on how Authorized Operators collect and share information, thus exerting greater control also over them.

8) Instrument of Monetary policy:

   With centralized management, PBOC could better enhance monetary policy transmission thanks to an improved monitoring control, and implement more targeted measures to influence the economy by managing the circulation of money and adjusting interest rates more directly (Fan Yifei 2021; Mu Changchun 2021). Jiemeng Yang (2022) finds that E-CNY will change the structure of money demand, speed up currency circulation, achieve better monitoring of

[179] Pettis, M., *Changing the Top Global Currency Means Changing the Patterns of Global Trade,* Carnegie Endowment for International Peace, 2022.

[180] Bencivelli, L., & Savini Zangrandi, M., *The Internationalisation of the Chinese Renminbi and China's Digital Currency Plans*. Istituto Affari Internazionali (IAI), 2023.; See: *Defenfing Americans from Authoritarian Digital Currencies Act* See https://www.congress.gov/bill/117th-congress/senate-bill/4313/actions.

reserves. It will increase volatility and impact currency multiplier. For transmission it will improve the effectiveness of the existing tools like medium term lending and pledge supplementary lending.[181]

For risk assessment we can count all those pointed in the first chapter: from monetary policy concerns, the cost of issuing E-CNY is not clear. It must be kept into consideration if PBOC will keep seigniorage for E-CNY and offset such profits to keep-up with the new costs for managing the overall infrastructure, while keeping it free to use for consumers and merchants. DC/EP is less exposed from the digital currency sovereignty risk, being itself a pioneer with international prospects. If PBOC want to effectively implement E-CNY for cross-border use it must expand further regulation for offshore accounts activities and limits, as pointed in the first chapter.

From the financial risk side, cybersecurity threats will affect DC/EP system and technical infrastructure like everyone else. Nevertheless, the fact that its technological specificalities are kept secret it could serve as a plus for impenetrability. E-CNY could become a vehicle for a new set of financial crimes and frauds that have started already (see Section 2.3.4.). Disintermediation risk is for now under control, being the system two-tier based thus granting commercial banks a fundamental intermediation role.

2.3.2 Government

Within the profitable characteristics for governments, we can find:

1) More control:

   Direct oversight and influence over how the operators manage their customer's funds.

2) Enhanced Tax Environment:

   E-CNY is envisioned also to be an instrument against tax evasion (White Paper; Mu Changchun 2022; BIS). Tax authorities would have direct access to transaction data. They would be able to collect taxes more directly with the use of smart contracts (Jiang 2023).[182] Gao (2022) consider that DC/EP can reduce tax risk for resource-based enterprises, and have a great impact in on the amount of invoices issued, the

[181] Gao, Y., *Mechanism and Countermeasure Analysis of DCEP Reducing Tax Risk of Resource-Based Enterprises* (*DCEP 减低资源型企业税收风险的机理与对策分析*), University of Liaoning (辽宁大学), 2022.

[182] Jiang & Lucero (2021) op. cit. pp- 269-269.

amount of wages and welfare payments and individual tax withholding and payment. So, as discussed in the first chapter, tax revenues will not increase thanks to interest rates, being E-CNY not interest bearing, but will increase tax revenues thanks to the fact that is account based. Following this principle tax evasion can decrease proportionally to the take up.[183]

3) Reshape Social Credit System:

   Li Jianwei et al. (2022) state that E-CNY will enhance credit data collection, improve speed and security of credit inquiries, and will raise efficiency for credit repair processes through automation. For a proper integration of E-CNY with Social Credit system the government should strengthen the limited legal framework regulating E-CNY.[184]

As stated before, the NPC (National People's Congress) has the fundamental role of literacy, educating End Users to E-CNY use, risks, rules. Only this way, and through extensive promotion and payment convenience, it can attain long-term take-up.

2.3.3. Commercial Banks

1) Increase in bank deposits:

   As we know CBDCs can reduce the demand for traditional deposits, with the result of decreasing deposit bases and affecting lending capacity and profitability (Section 1.5.3). Commercial Banks will have to adapt their business models as well as their technical infrastructure to comply with the new role. By linking the E-CNY wallet to commercial banks (in its soft version) it helps in promoting financial inclusion. As the PBOC foresee, it can encourage more people, especially in rural areas where many remain unbanked, to open bank accounts and increase deposits. However, local banks and financial institutions oftentimes are not yet linked to the E-CNY platform, a matter which PBOC is trying to find solution through partnering with Rural Credit Bank

[183] Gao, Y., *Mechanism and Countermeasure Analysis of DCEP Reducing Tax Risk of Resource-Based Enterprises* (*DCEP 减低资源型企业税收风险的机理与对策分析*), University of Liaoning (辽宁大学), 2022.

[184] Li, J., *How the E-CNY Reshaping Social Credit System in China?* (*数字人民币如何重塑我国社会信用体系?*). Shandong University Journal(山东大学学报), 2022(06), 121-130.

Capital Clearing Center to converge E-CNY services to a "single access point" (Greene 2021).[185]

2) Avoid disintermediation:

   Two-tier operation model prevents disruptions to the financial system by delegating customer interactions to Authorized Operators, i.e. commercial banks or the other financial institutions. This approach limits the central bank's risk exposure and responsibilities, while also dealing with concerns about disintermediation of commercial banks.[186]

3) Lowering operational costs:

   This concerns the reducing of operational costs related to manage physical cash, storage, transportation, handling and all the related personnel (Guo Lu 2020).[187] Clearly all new set of costs will rise up, and there are still no details as to the extent. The more complicated, decentralized, multilayered, secure, fast, interoperable will be, the more it will cost. Even though White Paper states that PBOC will not charge Authorized Operators for exchange and circulation services, it remains to be seen if they will not bear no cost at all if they need to change their business model.[188]

4) Enhance Customer Retention:

   Gao (2022) claims that CBDC can better keep customers tied to their bank account. Through the App experience banks can offer more value-added services, promoting other banking products and enhancing customer loyalty.[189]

5) Reduced need of physical branches:

   Gao also stated that CBDCs will accelerate the already ongoing trend of reducing banking branches and services *in situ*. This characteristic is double edged. As already analyzed, the Bank of Canada was suffering for this trend, and trying to cope with closing branches in isolated locations problem through CBDC. It will all depend on

[185]Greene, R., *What Will Be the Impact of China's State-Sponsored Digital Currency?* Carnegie Endowment for International Peace, 2021.

[186] Galbraith, A., & Shen, S., *China Central Bank Launches Digital Yuan Wallet Apps for Android, iOS*. *Reuters*, 2022. Consulted last 17/9/24

[187] Guo, L., *Research on the Impact of The People's Bank Of China Digital Currency Implementation on Commercial Banks* (*央行数字货币推行对商业银行的影响研究*). *农银学刊*, 2020(06), 59-61.

[188] White Paper (2021) p.8.

[189]Gao, Y., *Analysis of the Impact of CBDC on Commercial Banks* (*央行数字货币对商业银行影响探析*). *时代金融*, 2022(11), 70-71+83.

the entity of services provided by commercial banks for CBDC, like short-term loans and the ease of convert cash into CBDC, for which a physical depository is needed.[190]

Risks concerning Commercial Banks, their relationship with PBOC, the currency and consumers are listed as follows:

1) Bank Run Risks:

   E-CNY App category two wallet bears RMB 500,000 (63558euro) balance limit with annual top-up limit from RMB 200,000 to RMB 1,000,000 and annual deposit limit from RMB 200,000 to RMB 2,000,000. Single transaction limit set at RMB 50000 (6355euro). Category one bears no limit at all. Such caps allow, without proper regulation, potential massive withdrawn of liquidity from banks, resulting to a decrease in liquidity, credit, increase in lending rates and financial crisis risk just as described in the first chapter. We're far from the BoI deemed 3000-euro wallet cap, even considering the complementary relationship between PBOC and Commercial Banks. In addition, we observed that even in case of no remuneration, bearing no caps at all it can result in a risk for bank runs toward CBDC if the interest rate turns negative.

   Greene (2021) observes that small Chinese banks don't have strong balance sheet as big state-owned banks. A rapid E-CNY take-up and financial uncertainty can lead to uncontained bank runs.[191]

   Another issue can arise from E-CNY App facilitating the opening of bank account. While this from one side could increase bank deposits, thus increasing financial inclusion, to the other side can increase deposit in smaller banks that can offer higher interest rate. At the same time deposits can flow out from smaller banks in times of volatility. Moreover, the general deposit base can be volatile since customers could easily move funds between banks, potentially undermining financial security.[192]

2) Balance sheet uncertainty:

   In order to ensure that E-CNY will not be over-issued, commercial banks are required to maintain a one-hundred percent reserve ratio (Fan Yifei 2022). As a result, E-CNY

[190] Gao Y. (2022) *Id.*

[191] Greene, R., *What Will Be the Impact of China's State-Sponsored Digital Currency?* Carnegie Endowment for International Peace, 2021.

[192] Greene R. (2021) *Id.*

should not have any derivative deposits or money multipliers. On the basis of the two-tier model, Mu Changchun (2022) clarifies that "commercial banks would need to reduce their reserves with the central bank to exchange for the equivalent amount of CBDC issued, thus the E-CNY issued to the public would remain as the Central Banks's direct liability".

Zhou Xiaochuan (2021) though, noticed that E-CNY is actually a liability of the second-tier institutions that *de facto* own the currency. These commercial banks liabilities would be backed by central bank liabilities held as assets by the institution that issue the E-CNY.[193] His point of view remains unchallenged, PBOC still did not made further specifications on the matter. In case it remains a 100% reserve rate, this could nonetheless impact credit expansion and lending rate of commercial banks (Gao 2022).[194]

Even though the pilot has been ongoing for four years now, PBOC or the major commercial banks, have made no in-depth analysis for what concerns compliance with LCR and NSFR ratios, potential shortening of the BS or the decrease in Payment Fees Revenues, a vivid concern for other CBs as stated in Section 1.5.3.1.

2.3.4. End Users

E-CNY App offers a fully digital product that is not new in Chinese digitalized life. Plus, E-CNY is already bound to Alipay and WeChat platforms. This is aimed to ensure no disruption in peoples' payment habitus. The subsequent section enumerates the motivations why End Users would adopt E-CNY and the reasons for which they would refrain from.

1) Free to use, instant, cheap mean of payment:

   As we know E-CNY App bears no costs for soft or hard wallets, no costs for holding balances, no transaction or transfer costs for consumer nor merchants. In addition, E-CNY uses settled upon payment model, through which in the moment the payment is made the settlement occurs instantaneously, increasing speed of transactions, in the current throughput limits already discussed.

[193] Zhou, X, *China's Choices in Developing Its Digital Currency System*, Caixin Global, 2021.

[194] Gao (2022) *op. cit p.*3.

The system is highly secure against external attacks, aided by its confidentiality measures. Its decentralized nature ensures resilience, eliminating single points of failure, and it operates continuously 24/7 with offline functionality as well.

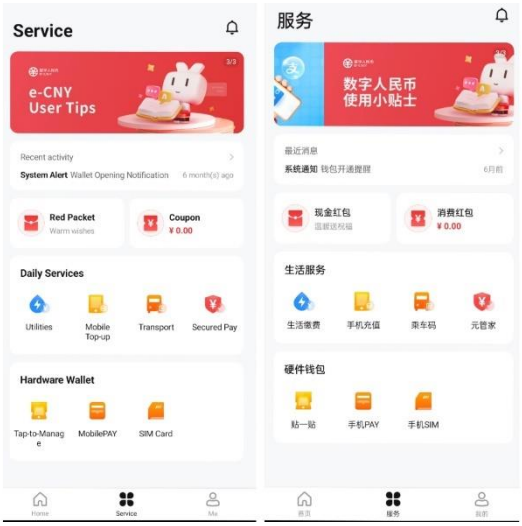

Figure 17 E-CNY App Services. Source: E-CNY App

2) Promotional activities:

Digital Red Packets are the main promotional instrument for E-CNY adoption. Users download the App, open a wallet, and can enjoy a 50-100 RMB Red Packet to be used by the adhering merchants in the shopping district hosting the promotion. As we will see, this is the main promotional activity together with loans, tax reliefs, wages payments. Reuters reported in 2022 Shenzhen issued RMB 30 million in Red Packets, Xiong'an new area RMB 50 million. At the time, they were intended to boost internal consumption after COVID crisis of demand.[195] It remains to be seen if these activities will help to the take-up in the long run. Users could open many wallets to enjoy the promotion but do not keep using it right after.

3) Payment services available:

The image shows the daily services available from the App for a Category 3 profile. It ranges from utilities payment, mobile top-up and transport. Instant transfer can be made by users just like Alipay and WeChat platforms do. Transfers and payments can be done offline, drawing from the balance credit, a feature instead very limited in Alipay and WeChat.

4) Payment solution for foreigners:

If we consult the Guide for Payment Services in China,[196] it states that as a foreigner you can download the App, open wallets and make payments with E-CNY. This could have been a great solution for foreigners in order not to open a Chinese bank account while enjoying the same digital payments services like Alipay and WeChat offer.[197]

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[195] Reuters, *China Uses Digital Yuan to Stimulate Virus-Hit Consumption*, 2022. Consulted 11/9/2024.

[196] http://www.pbc.gov.cn/eportal/fileDir/goutongjiaoliu/resource/cms/2024/05/2024052411252176674.pdf

[197] Interesse, G., *China's Digital Yuan App Gets a Boost: New Features Enhance Convenience for Foreign Users*, China Briefing, 2024. Consulted 11/9/2024;

In the last months however, the government seems to have had an afterthought. On March 2024 it announced a raise of Alipay single transaction limit from 1000 to 5000 USD and annual cap from 10000 to 50000 USD for overseas travelers. Ant Group, after an urge of the PBOC, allowed foreigners to bind oversea bank cards to Alipay. Tencent made the same upgrade for WeChat. Theoretically Visa and Mastercard credit and debit card are accepted. As a seal to this new turn Mastercard is entering in a JV with NetsUnion, reporting the start of processing payments made in China using Mastercard issued by domestic banks. This can strengthen global connectivity, enhance transnational transactions but limits the initial potential purposes of E-CNY, as a solution for foreign travelers and residents.[198]

The E-CNY App actually poses limits to foreigners. They, at present, cannot step-up from the Category 3, since the system does not accept foreign ID/passports as a document. In addition, users cannot bind a foreign bank card to the App, thus greatly limiting the boasted intentions. Moreover, PIPP states that "if you're not located inside China, or have left China, please opt out of the services provided by this Product and notify us. Since it's not the intention to provide services to individuals outside China or process their personal information" (PIPP Appendix). So, the international solution for E-CNY App is still far from being implemented.

5) E-CNY and US-sanctions:

   E-CNY could serve as an alternative for countries under U.S. sanctions to trade with Chinese companies, or for U.S.-sanctioned Chinese firms to continue operations. By utilizing E-CNY accounts within its own network, these transactions could bypass conventional international payments circuits, which are typically subject to U.S. regulation.[199]

On the other side the characteristics that hinder the adoption for users:

1) It will be difficult to make people want to adopt it, change habitudes in an already highly digitalized environment. Moreover, Alipay offers more possibilities such as investing insurance and consumer lending. E-CNY is now developing lending and

[198] https://english.www.gov.cn/news/202403/01/content_WS65e10df0c6d0868f4e8e4781.html; https://english.www.gov.cn/news/202403/02/content_WS65e26742c6d0868f4e8e4881.html; https://www.mastercard.com/news/ap/en/newsroom/press-releases/en/2024/mastercard-jv-switches-first-domestic-transaction-in-china/;

[199] Laband, J., (2022); Greene (2021).

insurance with some scattered pilots, but the system is still away from the broad take-up.[200]

Alipay and WeChat do charge more costs for merchants, but is mostly free for consumers. What are the reasons that will move them, besides the already displayed ones, to change from an already seamless solution. Most likely they will complement each other, the final result will depend on the government resolutions in promotion, raising awareness and costs for End Users.[201]

2) Privacy concerns:

E-CNY introduces several privacy implications that impact both consumers and merchants. Section 2.3.2. displays that "managed anonymity", ensures anonymous small-value transactions, but high value and suspiciously reiterated ones might be traced. However, this introduces concerns about PBOC and government authorities access to users' economic data, which can potentially lead to violations of property rights, raising concerns over mass surveillance and centralization of authority. This level of access could extend beyond economic activities to encompass sensitive personal data such as health information and consumption habits. ID anonymization is applied between wallets, but Authorized Operators still gather a vast amount of personal data due to AML/CFT regulations. PIPL regulate data use and share, but as we know its application to E-CNY remains unclear.

The potential for unauthorized access or breaches adds further layers of concern about data security within E-CNY system, especially considering the centralization of data within the PBOC and the lack of transparency on data sharing and surveillance protocols.

Transparency towards End Users is pivotal for building trust between stakeholders and to the platform.

3) Not a universal legal tender status:

Section 2.3.1. highlight that although E-CNY possess legal tender status thanks to the Law of the People's Bank of China amendment, it doesn't yield a universal legal

[200] https://www.reuters.com/technology/former-pboc-official-says-chinas-digital-yuan-is-little-used-caixin-2022-12-29/

[201] Li, Y., Wareewanich, T., & Chankoson, T. (2024). *A Study on Influencing Factors of Willingness to Use E-CNY Based on Logistic Model*, International Journal of Interactive Mobile Technologies (iJIM), 18(04), 112–123, 2024.

tender status. Undoubtedly, it broadens efficacy being available offline in comparison to the others PSP platforms, but indeed needs electricity and a smartphone to be used, limiting usability against cash.

4) E-CNY fraud:

   It has been reported 3 cases in Jiangsu of digital frauds using E-CNY. A man reported being tricked to transfer E-CNY 20000 toward another person's account for a financial investment that he believed to be compliant with regulations. Another user has been frauded receiving calls from self-calling police authorities, being communicated that its personal E-CNY account has been frozen due to suspected ML activities. User has been deceived to transfer RMB 24000. Another man has been fouled to download a corrupted software from WeChat and been forced to spend RMB 65000.[202]

   If Jiang (see above Section 2.3.1.) is correct these people should be refunded by PBOC, but for now there's no update on the matter.

2.3.5 Technology and Service providers

Mu Changchun (2022) asserted that Authorized Operators, PSPs, fintech companies and telecommunication operators, will operate in a market-driven competitive environment. So, the most efficient, innovative dynamic resolution in payment product design, service exploration, product safety, maintenance and payment processing, can obtain a greater relevance in the continuous building of a system that is still open to updates and modifications.[203]

Recalling *Section 1.5.5*., Technology Providers are responsible to keep the infrastructure secure and functional. PSPs will ensure resilience and interoperability between PSPs, like E-CNY and WeChat/Alipay platforms. These Authorized Operators if delegated by Commercial Banks and approved by PBOC will share carry AML/CFT requirements. Responsibilities facets are not clear, but if they do, they will burden the subsequent data analysis and safekeep.

Data leakages, external attacks and systemic risks are the Achilles' heel of the system delegated to their responsibility. Their future role will also depend on efficiency of the management in the alleged dynamically competitive environment.

[202] http://www.zjg.gov.cn/zjgszwz/mzjs/202312/05e7a02e93ec49118050bb1d54993a5b.shtml

[203] http://www.pbc.gov.cn/en/3935690/3935759/4749192/20221229133501388 68.pdf)

Pertaining costs, PBOC generally stated that will not charge Authorized Operators for exchange and circulation services (see note 183 section 2.3.3.). This doesn't specify what for managerial, safekeep and innovation costs that will occur.

2.3.6. International Organizations

International Organizations are playing a significant role in shaping CBDCs' theoretical tenets, mostly for what concerns the future of domestic and international payments (see Section 1.5.6.). They didn't delve so deep in the realm of E-CNY but they have been present on some extent.

BIS have been the more collaborative with PBOC. Beside the extensive research on CBDCs it has published a paper on E-CNY explaining its features and international vision. Moreover, it patrocinated the mBridge project, thus fostering CBs international cooperation.[204]

The Atlantic Council has been, together with BIS, a resourceful channel for all the ongoing CBDCs projects and the E-CNY. They published specific reports for DC/EP, its international purposes, as well as all the projects for domestic services proposed by Operators.[205]

IMF has been actively involved in examining E-CNY. It produced reports and presentations -one presented by Mu Changchun- assessing the potential impacts of the E-CNY on international trade, financial stability and monetary policy, providing various insights and recommendations for integrating CBDCs into the global financial architecture.[206]

World Bank and WEF kept more general on CBDCs and wholesale CBDCs without specifically delving into E-CNY comments, advises or analysis.

A wider PBOC and E-CNY Research Institute opening toward dialogue with international organizations can better help mutual understanding, global effects of CBDCs and possible future CBDC cross-border projects.

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[204] https://www.bis.org/publ/bppdf/bispap123_e.pdf;

[205] Atlantic Council, *A Report Card on China's Central Bank Digital Currency: The E-CNY*, 2023; Atlantic Council, *Practice Makes Perfect: What China Wants from Its Digital Currency in 2023*, 2023.

[206] Mu, C., *Central Bank Digital Currency and the Case of China*, International Monetary Fund (IMF), 2022; Fan, H., *Central Bank Digital Currency and Digital Money in China*, CLSA, 2022; People's Bank of China (PBOC), *E-CNY Introduction*, Conference at IMF, 2023.

PBOC generated a product that will face a real challenge to penetrate in the already well rooted Chinese digital payment habitudes. E-CNY is trying to spread across services and e-commerce platforms like Didi and Taobao, but the final words will come from the End Users.

PBOC and Authorized Operators will have to be transparent concerning which data, by whom and to where are collected, analyzed and stored. E-CNY specific legislation has to be implemented, as well as specific referments to current laws concerning privacy and information collection and sharing.

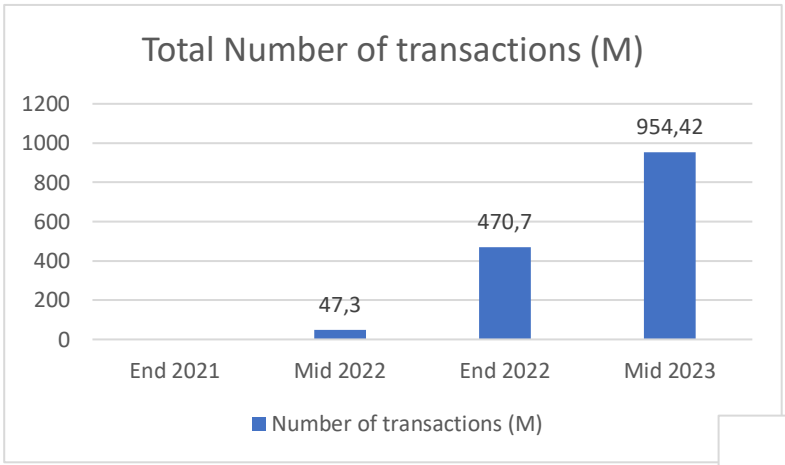
Promotional activities have to be sided with the educational ones. A real convenience has to rise from E-CNY otherwise will remain a state-backed product with doubtful utility.

PBOC has to be clearer concerning liquidity and funding compliances, being more open publishing more specific reports with broader data. This is also aimed to build better relationships with other CBs and International Organizations, if it really wants to be taken as an example for CBDC design, infrastructure and use, really expanding internationally.

Chapter 3 – E-CNY National and "10+1" Pilot Circulation Analysis

3.1 National Data

The present chapter analyzes E-CNY circulation. First, we will take a look at the overall national data concerning the cumulative total number of Wallets Opened, Transaction Volume and Number of Transactions from 2021 to mid-2023/2024.



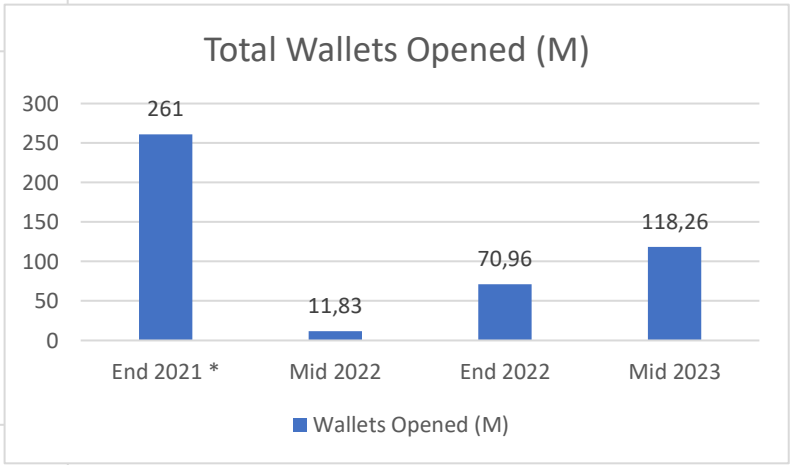
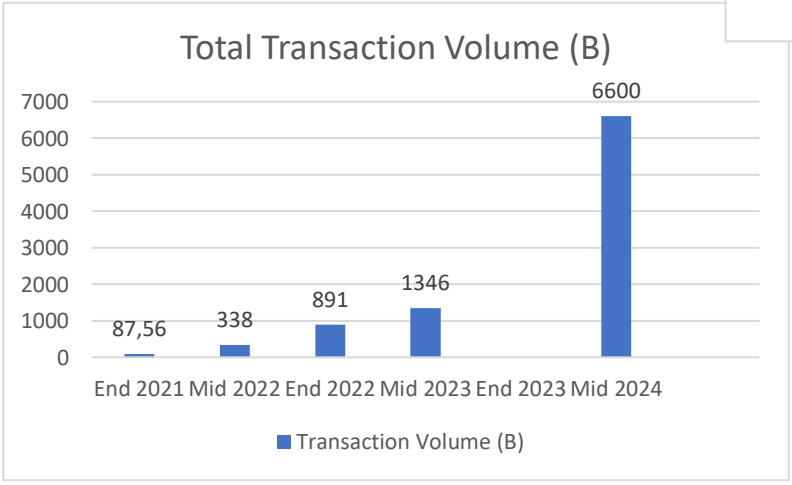


Figure 18, 19, 20: Total Number of Transactions, Wallets Opened and Transaction Volume from the end of 2021 to mid-2024. Source: https://m.gmw.cn/baijia/2022-01/18/1302768629.html; https://baijiahao.baidu.com/s?id=1806868683325205513&wfr=spider&for=pc; https://www.imf.org/-/media/Files/Conferences/2023/11/sti-25th/e-cny-intro-imf.ashx



	Mid 2022	End 2022	Mid 2023	YoY Growth
Tot N. Wallets	11,83	70,96	118,26	900%
Tot N. Transactions	47,3	470,7	954,42	1918%
Tot T. Volume	338000	891000	1346000	298%

Table 6 Total Number of Wallets, Total Number of Transactions, Total Transaction Volume Mid-2022 to Mid-2024 Author's elaboration.

Comment

A foreword before delving into breakdown of the data: consistency has been a major issue in the research for this thesis. Oftentimes data are missing, incomplete, sometimes incoherent. Concerning aggregated data I could count on End-2021, End-2022 data. Mid 2024 only reports Total Transaction Volume at the end of May. The rest of aggregated data I deduced it from a series of slides in a E-CNY presentation at IMF in 2023.

Secrecy might be a reason for non-divulgence, without inferring further reasons unbefitting the objectivity of a thesis.

Wallets

Wallets present a very high number in the end of 2021, drastically decreasing in 2022 to rise up again progressively. This is due to the fact that before 2022 there was a Beta Version of the E-CNY App. The present version of the App was published in 2022, and the count has been restarted.[207]

In the present research all referments to Wallets count for the total cumulative number of wallets opened, i.e. Personal Wallets, Soft and Hard Wallets, Corporate/Public Wallets. This explains why in some cases, as we will see, there will be more wallets than residents in the pilot cities. Reason lies in the fact that the majority of times wallets are counted together, seldomly there's specification, and in any case it's neither organic nor consistent.

From Mid-2022 to End-2022 there has been a 500% growth.

From End-2022 to Mid-2023 a 66% growth.

YoY (Mid-2022 to Mid-2023) we witness a 900% growth.

First, this might be due to the fact that the new E-CNY App came out, so basically all the people that already had a wallet immediately started to download the new App platform. Second, the population base of the pilots increased considerably in the last two years, scaling up from nine cities and one province to seventeen provinces. Despite the remarkable increase,

[207] https://baike.baidu.com/item/%E6%95%B0%E5%AD%97%E4%BA%BA%E6%B0%91%E5%B8%81/59801552?fr=aladdin.

which complies with the ease of access conceptually constituting the platform, this doesn't explain however why the number is still below the impressive 261 million, a figure that exceeds twice the total population of the pilots, more than two wallets per person at least.

Total Transactions

This numbers represent the cumulative number of the total transactions and transfers made with E-CNY, either using the App or the Hard Wallets.

From Mid-2022 to End-2022 there has been a 1000% growth in the number of transactions.

From End-2022 to Mid-2023 another 102% increase.

YoY (Mid-2022 to Mid-2023) growth of total transactions is 1918%.

This massive YoY result displays that beside joining the platform and opening wallets, users are employing it, increasing the user engagement. The growth in total transactions outpaces the 900% growth in wallets implying that users are more engaged over time. Again, an ulterior growth is expected in the future, with the increased territorial activity of the pilot and a continuous increase of the merchants accepting E-CNY payments and the Use Case Scenarios. Use case Scenarios refers to the different contexts or use cases where the E-CNY can be applied, i.e. retail shops, e-commerce platforms, transportation, utility bill payments, government services. Applicable Scenarios and Merchants Accepting E-CNY were respectively 8,08 million in End-2021 and 5,6 million in Mid-2022.

Transaction Volume

This data counts the total cumulative sum of all the transfers and transactions in every kind of payment and service through E-CNY, comprising also funds, subsidies, tax payment, loans, Red Packets, lottery tickets.

From End-2021 to Mid-2022 there has been a 260% increase.

From Mid-2022 to End-2022 a 163% increase.

From End-2022 to Mid-2023 a 51% increase.

From Mid-2023 to Mid-2024, so with half a year data missing, there has been a 390% increase.

YoY (Mid-2022 to Mid-2023) Growth of Total Transactions Volume is 298%.

Despite the spiking growth in volume, this rate is proportionally lower than the YoY wallets opened and the Number of transactions. This means that user base and engagement has increased but the value for each transaction proportionally is decreasing.

The vast majority of the volume is carried by one sole city, Suzhou, that with 5 trillion RMB is dealing with 75% of the total cumulative volume alone.

All data shows a stead and rapid increase, due to the territorial increase of the pilot and consequently of the population. This implies a broadening of the user base, applications and merchants accepting payments with E-CNY. Promotional activities and broadening of services.

Here below an analysis of the Average Spent per Wallet, the Average Spent per Transaction, the Average number of Transactions per Wallet. I remind that I kept "Wallet" and not "person", because each person can have multiple wallets, so we do not know effectively how many people are using it, nor we know the number of wallets that are actively making transactions, these calculations are made on averages based on the total values stated above.

	Mid 2022	End 2022	Mid 2023	Average	YoY Growth
Average Spent per Wallet	28571,43	7793,12	3847,45	13404,00	-87%
Average Spent per Transaction	7145,88	1306,094	940,6268	3130,866	-87%
Average Transactions per Wallet	3,998	5,966742	4,090309	4,685	2%

Table 7 Comparison between Wallets, Number of Transactions and Transaction Volume. Mid-2022 cells are marked because there should be a comparison from End-2021 but data is not completely available. Author's elaboration

As expected, the Average Spent per Wallet has decreased significantly by 87% on YoY basis. Although the platform has increased its scale and reached a wider audience, this suggests that new users are spending less in average. This can be due to the fact that they are engaging in smaller transactions in general or the pattern is reflecting a broader user diversity.

The Average Spent per Transaction also dropped showing an 87% decrease in YoY, also implying that users are engaging in lower-value transactions or spending less.

However, the Average Transactions per Wallet grew only by 2% on a YoY basis. This denotes that the users are still little engaged with the platform. The 50% increase between Mid-22 and End-22 period didn't sustain in Mid-2023.

Albeit the sharp decrease in Average Spent per Wallet and Average Spent per Transaction, Wallets Opened grew YoY by 900% and Total Number of Transactions by YoY 1918%, increasing a lot the user base and usage, thus attaining its purpose of social financial inclusion. It would be expected that from these two spikes there would have been a great increase in

Average Transactions per Wallet, which in comparison is showing a very small rise. This could imply that a lot of users are opening wallets but then don't use them and only some wallets are active. Unfortunately, there is no data on Wallet activity. The Average Spent per Transaction drives the assumption toward mid- to higher-value activities than small-value transaction ones. These can reflect more B2B transactions, loans payments, occasional purchases than routinary, daily ones.

Data show a tendency to shift to smaller transaction value, but the Average Transactions per Wallet reports that it's still not the case. This could mean that some users are employing the platform for everyday payments while others for significant expenditures.

Assuming that the platform is focusing on a strategy of inclusivity and accessibility, being that one of the E-CNY purposes, it should increase Average Transactions per Wallet ratio, since it's the main ratio conveying user engagement. With such broadening of User Base and Total Transactions Number the platform must ensure that can sustain the increase of the scale, keep increasing the user base and engagement. The more the platform is used for daily life activities, like commuting and retail purchases, the more it penetrates in everyday habitudes becoming a constituent of peoples' lives just as the other's PSPs like Alipay and WeChat.

Clearly, more YoY data would be needed to make better hypothesis on trends. Spike grows or oscillations are paradigmatic of an early-stage platform that still needs to balance, but nonetheless is massively promoted. Incentives and promotions can also lead to short-term promotional spikes, that lead users to open wallets for Red Packets in shopping streets, lottery tickets, discounts, tax incentives. Once the promotion ends, a massive post-incentives decrease is witnessed, in this case due to a drop-out of digital wallets perceived as not useful anymore.[208] We will see if that is the case looking at the consumer engagement to the wallet openings through the years.

3.2 "10+1" Pilot analysis

Between the end of 2019 and the course of 2020, the "10+1" E-CNY pilot is launched. The cities comprised are Chengdu, Suzhou, Shanghai, Xiong'an, Xi'an, Shenzhen, Dalian,

[208] See Kotler, P., P., Koshy., K., & Jha, M. (2013). Marketing Management. Prentice Hall.

Qingdao, Changsha and the Province of Hainan. The "+1" is the Beijing 2022 Winter Olympics in which E-CNY payments has been rolled out in competitions' areas.[209]

Even though not officially stated, reasons behind the choice of these cities can be deduced. First of all, a territorial reason: as it can be seen from *Figure* 21 cities are located all over the country from the Dongbei region with Dalian, to the hinterland with Xi'an and Chengdu, to the South with Hainan and Shenzhen (also a SEZ), and the East with Suzhou and Shanghai. Secondly, the GDP distribution: Shanghai, Suzhou, Shenzhen and Chengdu are ranked in the top ten cities for the highest GDP, Qingdao and Changsha come 13th, Xi'an 23rd. Dalian and Hainan follow to 30th and below, so a very wide range of GDP from the highly economic developed cities to the developing ones. The third reason is for technology and innovation. These cities, like Shanghai, Suzhou and Chengdu, are highly digitalized. Xiong'an is more an innovation area located in Baoding (保定市) than a city itself. Diversified cities in location, GDPs, level of technology use, digitalization and innovation propension for a pioneering CBDC pilot.

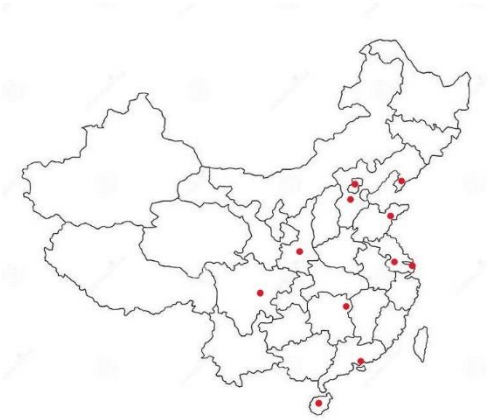


Figure 21 Map of the "10+1" pilot locations. Author's elaboration

3.2.1 Quantitative and qualitative data analysis

Pertaining the pilot cities data, I examined throughout Google, Baidu, City Municipalities' Official Websites, 163.cc, Sohu and Baijiahao. I searched for thousands of pages but quantitative data remain uncomplete, almost completely missing as in the case of Qingdao, Dalian, and Shenzhen or not present at all. This last is the case of Chengdu and Shanghai for which only some qualitative data on Promotional Activities and Coverage are disclosed.

Quantitative data, whenever possible, will be compared with residents' population for what concerns the number of wallets opened and the Cities' GDP for what concerns the Transaction Volume. Qualitative data are analyzed firstly through coverage, i.e. how many merchants are accepting E-CNY payments and how many use case scenarios, ranging from

[209] Nanfang Dushi Bao, *Here Comes the Digital RMB! Chengdu, Suzhou, Xiong'an New Area and Other Places Took the Lead in Carrying Out Pilot* (*数字人民币来了！深圳、成都、苏州、雄安新区等地率先开展试点*). *Sohu*. Published on August 14, 2020. Last consulted on 14/9/24; White Paper (2021) p.13.

transport, public services, elderly care, retail consumption and dining. Secondly, they will be analyzed in consideration of promotions and discounts, loans, funds, subsidies, tax payments and city's peculiar innovative projects analysis. Tables on Wallets Opened, Number of Transactions and Transaction Volume, as well as their ratios to GDP and Resident Population are disposed in the *Appendix* of the present research. In addition, due to the relevant amount of *Sitography* covering the subsequent section of comments, all the references have been gathered by city under the *Sitography* heading, in order not to burden the text with footnotes.

Comment

- *Shenzhen*

Shenzhen	YoY 2021-22	YoY 22-23	YoY 23-24
Wallets Opened		1%	27%
Number of Transactions			
Transaction Volume			

Table 8 Shenzhen's Wallets Opened, Number of Transactions and Transaction Volume YoY 21-21 to 23-24. Author's elaboration.

Shenzhen shows complete data only for 2022, in which 28 million wallets were opened, 1,29 million transactions executed for a total of 37,6 billion E-CNY. The only YoY ratio on these data regards the Wallets Opened in 22-23 with a slight increase of 1%, and in 23-24 for a 27% increase. If we compare this data with the proportion of wallets to the total resident population, we notice that wallets are the 159% of the population, roughly 1,5 wallets per person, a ratio that grows to 200% for the first half of 2024. In 2022 the Transaction Volume was totaling for 1,16% of the GDP. Unfortunately, we cannot monitor the evolution of the other ratios.

As per the Average spent per Wallet the numeric value is 83% below the End-2022 national average. Average Spent per Transaction is impressively 2131% more than the End-2022 national average. Average Transactions per wallet are 99% below the national average. This means that a lot of wallets have been opened but very few are used, and those used are making remarkably high value transaction compared to the national average that was already quite high (although already decreasing from the End-2022), a data that will be overpassed only by Suzhou.

Shenzhen	2022
Average Spent per Wallet	1342,86
Average Spent per Transaction	29147,29
Average Transactions per Wallet	0,046071429

Table 9 Shenzhen's Average Spent per Wallet, Average Spent per Transaction and Average Transactions per Wallet 2022. Author's elaboration.

Coverage in 2021 was starting to expand with 3000 merchants in supermarkets, shopping districts, pedestrian streets, poverty alleviation street areas. Merchants increased to 15000 in 2022 and to 2.1 million in 2023. In 2022 Shenzhen implemented the “E-CNY 1-Cent Bus Ride” “数字人民币一分钱乘车”, with city wide coverage, then expanded in 2023 to the metro lines with the “E-CNY Co-branded Card” “数字人民币联名卡”. In the same year also DiDi implemented the service payment in E-CNY. In addition, E-CNY integrated with Octopus, a PSP used in Hong Kong, expanded also in Shenzhen. In 2024 started to promote E-CNY hard wallets for foreign tourists to pay for public transport and retail payments.

Policies and activities are quite active since the end of 2021. Promotional activities found space during seasonal celebrations like Spring Festival in Longhua District in which 20 million worth of E-CNY were distributed in 2021 and 25 million in 2022. In 2022 Shenzhen distributed in collaboration with Meituan another 30 million E-CNY in digital Red Packets for consumer stimulation policies as a form of post-pandemic economic recovery. Meituan then reported consumers had increased transaction volume to the 52000 merchants adhering on their platform. Other consumer incentives are found in dining vouchers for 60 million E-CNY and 400 million E-CNY in shopping vouchers. Shenzhen carried on a total of 73 E-CNY promotional activities for 570 million E-CNY that year. Promotions followed in 2023 and 2024 in Luohu and Bao’an districts with digital Red Packets, cultural and sport consumption activities in vouchers and Red Packets. A typical slogan was the one also shared in Suzhou “From Taste to Normal” “从尝鲜到常态”, evocative to the willing to surge E-CNY to a daily payment solution. In the end of 2023 in Luohu an E-CNY Industrial Park has been inaugurated opening rent-free spaces and granting subsidies to invest in innovative start-ups and financial innovation.

Subsidies range from “cultural benefit vouchers” “文惠券” aimed to foster demand in cultural industry after the pandemic equal to 25 million E-CNY, a solution replicated the next year with 50 million E-CNY to be spent in performing arts, movies and books. In 2022 Shenzhen promoted a subsidy program for the purchase of a new car from 5 to 20 thousand E-CNY, with 50 million E-CNY cap. It’s a practice noticed also in Suzhou, but this last did it for green vehicles purchase.

Funds of notice count for 616 million E-CNY to 2422 small and micro enterprises from 2020 to 2022 to improve financial efficiency and stabilize business operations in form of loans.

Shenzhen used E-CNY for salary payments, a promotion that has been used among the pilot cities, mostly for the public sector, in this case for wage payment of 14000 public officials.

In order to further promote digital taxation Shenzhen is developing tax payment solution for companies and citizens, and non-tax payment with E-CNY for large corporations as for instance China Merchants Bank.

Shenzhen settled its strategy considering its territorial proximity with Hong Kong. It developed cross-border/cross regional services like income tax payments, transport across Guangdong, Hong Kong, Macao Greater Bay Area, cross-border consumption activities for Honk Kong residents living in Shenzhen and for visitors. It also invested in social welfare with provident funds services with E-CNY.

Shenzhen is also experimenting E-CNY in supply chain management for payments, payrolls and transfers, and experimenting in the prepayment sector through smart contracts. Agricultural Bank of China and China Construction Bank were involved for more than 112 million E-CNY. They invested in promotional activities to raise awareness on prepayment fund management through E-CNY for sectors like education, healthcare and dining, elderly care, fitness and entertainment which can overcome problems such as refund difficulties and fund security. From 2023 loans are also lent in the form of "prepaid loans" through E-CNY.

Shenzhen promotional activities were by one side aimed to popularize E-CNY for daily transactions, but from the only 0,04 average transaction per wallet doesn't seem to have worked as planned. To the other side is aiming to sustain demand and consumption for small and micro enterprises with funds, subsidies and loans, facilitating also tax payments for SMEs and corporations. Innovative activities in Shenzhen are found in experiments using E-CNY smart contracts to prepayment sector.

Unfortunately, we lack of data to make assumptions on Averages transactions per wallets, Average spent per transaction and Average Spent per Wallet after 2022. These would have help understand if or which strategies were successful.

- *Suzhou*

As introduced, Suzhou is the best performing pilot city in terms of Transaction Volume, carrying alone 75% of the total. In 2022 the city opened 20 million wallets, 9,1 million in 2023 with a 45% YoY increase, but stopped in the first half of 2024. The proportion of the wallets on the total resident population is 156%, similar to Shenzhen's proportion, increasing in on YoY basis by 45%, getting to 225% of wallets to population in 2023.

Suzhou	YoY 2021-22	YoY 22-23	YoY 23-24
Wallets Opened		45%	1%
Number of Transactions		700%	
Transaction Volume		1047,1%	28%

Table 10 Suzhou's Wallets Opened, Number of Transactions and Transaction Volume YoY 21-22 to 23-24. Author's elaboration

The Number of Transactions raised sharply on 22-23 YoY basis by 700%, but the most astonishing value regards the massive 1047% increase 22-23 YoY in Transaction Volume, counting for 144% of the city's GDP, that gets to 91% of half 2024 GDP, so decreasing the growth to 28%. This result can be explained through several reasons that are destined to remain hypothesis. It could be due to an overestimation of E-CNY transaction Volume, the use of E-CNY for large-scale financial investments, double counting, high volume B2B transactions or the inclusion of cross-regional transactions then attributed to Suzhou even if they occurred elsewhere.

Suzhou	2022	2023	2024	Average	YoY Growth 22/23	YoY Growth 23/24
Average Spent per Wallet	16923,84	122085,05	37376,83	58795,24	621%	-69%
Average Spent per Transaction	336633,66	503536,07		420084,9	50%	
Average Transactions per Wallet	0,05	0,24		0,15	382%	

Table 11 Suzhou's Average Spent per Wallet, Average Spent per Transaction and Average Transactions per Wallet 2022 - 2024. Author's elaboration

Pertaining the Average Spent per Wallet, Suzhou is above National End-22 average by 110%. The ratio cannot but increase in 2023, a deduction based on the 603% 22-23 YoY increase of the Average spent per wallet, that however is seeming to rebalance, looking at the -69% on the 23-24 YoY.

The Average Spent per Transaction is 25675% higher than national End-2022 average, a value that increases by 50% on 22-23 YoY basis. This can find explanation in very high-value B2B payments or financial investments, that however cannot substantiate in proof of event. This inference is also sustained in the low Average Transaction per wallet, 100% below the

National End-22 Average, that however grows by 382% on YoY basis, thus remaining at 0,24 transactions per wallet. Such low value sustains the thesis of high-value transactions, a value that also clashes with the 29 million wallets opened that are probably unused.

In Suzhou, although seeming a national success due to this massive output, and in consideration of the abrupt decrease in the Average Spent per Wallet (69%) and the Average Spent per Transaction, it appears that E-CNY is employed by very few users for high-value transactions, not really for daily activities. If PBOC purpose is to create a financial inclusive service that can compete with private PSPs, it must revive user engagement of people that most probably opened more than one wallet to enjoy a promotion or a discount and then quitted using it. It could attain it through medium-term promotion or discounted E-CNY subscriptions, that would sustain more transactions with a lower-value.

Pertaining Coverage, Suzhou in 2021 had 20000 use case scenarios, which expanded in 2022 comprising 485000 merchants and 930000 scenarios. In 2024 coverage expanded: accepting merchants became 790000, 57% of scenic spots accept E-CNY, 6 thousand supermarkets, 50% of public hospitals and universities, 52% of busses and 68% of metro-lines. In terms of public service Suzhou reached 100% coverage in water, electricity, gas, tv and telecommunication fees. If Suzhou wants to promote E-CNY to daily activities should increase commutes acceptance to 100%, supermarket and scenic spots discounts and maybe short- medium- term subscriptions.

In 2024 overall loans lent in Suzhou amounted to 24000, totaling 153 billion E-CNY in the first half of 2024, presumably more to companies than to private citizens. A 2023data is inconsistent with this statement, affirming local banks issued 59000 loans in 2023 only for 290 billion E-CNY. Some of the loans has been publicized for rural revitalization and grain collection, together with discounts for agricultural products.

Promotions are present but decreased conspicuously from 2022, however totaling 70 billion E-CNY only in the first half of 2024 summing all 260 promotional activities. Shopping streets promote E-CNY trough discounts and hundreds of millions E-CNY in Red Packets. Promotions occur during seasonal festivities and celebrations like “Taste of Jiangsu” “江苏味道” and “Spring Benefit Jiangsu” “春惠江苏”, Autumn discounts from Suzhou to all villages and the cities nearby, “Digital RMB Suzhou New Year's Goods Festival JD Special” “数字人民币·苏州年货节京东专场” in collaboration with JD.com and “Watery Jiangsu” “水韵江苏” just to cite some, with the shared slogan “From Taste to Normal” (see above).

Wages Payments for Civil workers was a 2022 activity that didn't followed up at least publicly counting for 639 million E-CNY, a broader investment than Shenzhen's one.

Subsidies are increasing but not close to the other promotions, fiscal and financial expenditures. Of notice there has been the Shangan co. Ltd subsidy for electricity bill payments, and the 10 billion E-CNY in subsidies for buying electric cars.

Due to the massive entity for single transactions Suzhou is more oriented to promote E-CNY for big companies' loans or investments, and this can find confirm in the massive output in values per transactions. Suzhou is trying to pursue solutions to improve User Engagement in everyday activities but the Average Transaction per Wallet is still far from being considered such, even after the numerous promotions and demonstrations in shopping districts, that are resulting ineffective to really attract users.

- *Xiong'an*

Xiong'an	YoY 2021-22	YoY 22-23	YoY 23-24
Wallets Opened			0%
Number of Transactions			54%
Transaction Volume		81%	30%

Table 12 Xiong'an Wallets Opened, Number of Transactions and Transaction Volume YoY 21-22 to 23-24. Author's elaboration

Xiong'an new area present a 2022 transaction value of 8 billion E-CNY. In 2023 increased by 81% to 144,8 billion E-CNY, equal to 16% of the GDP, a decrease from the 22's ratio by 23%. In 2023 wallets represent 136% of the total resident population of the area, totaling 1,64 million wallets opened in 2023. In 2024 we witness a 0% growth in wallets opening and a decrease in the Transaction Volume to GDP to 10%, even though Transaction Volume grew by 30% in the first half of 2024.

We have only 23-24 YoY data pertaining the Number of Transactions, reporting a 30% growth with 6.4 million transactions in the first half of 2024.

Concerning the Average Spent per Wallet, we must compare 2023 Xiong'an data to End-2022 and Mid-2023 national data, because End-2023 national data aren't available at the moment. Comparison displays a 13% higher value than the End-2022 national data, and 129% above Mid-23. The value decrease by 70% in the 23-24 YoY, either because the 2023 data isn't counting 2021 and 2022 Transaction Value subtraction (as done per the others when possible), or either due to the fact the data count only for half a year.

Xiong'an	2023	2024	Average	YoY Growth
Average Spent per Wallet	8829,27	2634,15	5731,71	-70%
Average Spent per Transaction	1216,81	675	945,90	-45%
Average Transactions per Wallet	7,26	3,902439024	5,58	-46%

Table 13 Xiong'an Average Spent per Wallet, Average Spent per Transaction and Average Transactions per Wallet 2023-2024. Author's elaboration.

Average Spent per Transaction in 2023 is below End-2022 national average by 6% but a 29% increase respect to Mid-23 national average. Despite the growth to national data, it decreases by 45% in the first half of 2024, probably due to a 54% increase in the number of transactions in the first half of 2024.

2023 Average Transaction per Wallet present a 23% higher value than End-22 one, projecting an enhanced user engagement with respect to the other cities analyzed till now. The decreasing 23-24 value is probably due to the value that counts only for half of the 2024, otherwise it would perfectly match 2023 values, characteristic that can be said also for the Average Spent per Transaction but not (for now) for the Average Spent per Wallet.

Xiong'an is presenting the most promising data for consumer engagement in "10+1" pilot. Wallets Opened exceed total population and an Average Spent that is decreasing over time toward lower-value transactions. Transaction Volume to GDP though is equal to 10%, a quite high ratio, considering only 7 transaction per wallet per year.

Concerning Coverage, some data are found starting from 2023. We know that 90% of the key merchants along the street implemented E-CNY payments and overall 26400 shops made E-CNY payments available. No further notice for 2024. Communication over coverage has been quite limited compared to Suzhou and Shenzhen.

Policies and Activities are not much advertised. As per the promotions in 2021 issued 3 million E-CNY in Red Packets of 50 E-CNY each to be spent by the adhering merchants.

Funds are counted from 2022, with "Xiong'an Science and Technology Innovation Vouchers" "雄安新区科技创新券", paid in E-CNY but the entity is not clear. Vouchers were also granted to innovative enterprises in the area to reimburse their investments. In 2024 Xiong'an has promoted funds to implement smart agriculture, i.e. hi-tech equipment and innovative techniques to incentive both rural revitalization, technology development, and E-CNY application.

News on loans started in 2023 reporting an intellectual property loan of 10 million E-CNY and for a loan to Xinyuan Garment Factory of 200 thousand E-CNY issued by China Postal Savings Bank.

In addition, Xiong'an implemented a unique service creating a Government Procurement Cloud Platform. This platform ensures secure management of government procurement processes, has increased the prepayment of the contracts by 30%-80%. E-CNY are used as guarantee for financing, a safe and easy access to loans in government contracts as well as interest subsidies to reduce financing costs.

Xiong'an has been poor in publication respect to Suzhou and Shenzhen, but is trying to implement more innovative ideas for businesses. Here, the target strategy is more focused on innovative enterprises funds and government procurements instead for daily purchases, in fact Average Spent per Wallet and Average Spent per Transaction shows the highest points after Suzhou and Shenzhen in 2022, even though it reports the Average Transaction per Wallet ratio. Numbers are far smaller than the other cities also in consideration to the 1,2 million population almost ten times less than the average population of the pilot cities.

- *Dalian*

The northmost city of the pilot after a 2022 slow start reported 15,8 million Wallets Opened 2023, a 1377% increase from the previous year more than doubling the Wallets to Population ratio. This ratio kept growing by 52% for half 2024, reaching the 318% of the total resident population of the city, the highest of the sort in this research.

Dalian	YoY 2021-22	YoY 22-23	YoY 23-24
Wallets Opened		1377%	52%
Number of Transactions			
Transaction Volume		101%	10%

Table 14 Dalian's Wallets Opened, Number of Transactions and Transaction Volume YoY 21-22 to 23-24. Author's elaboration.

Transaction Volume spiked between 2022 and 2023 by 101%, reaching 20,9 billion E-CNY, amounting to 1,2% of the local GDP, a ratio that is decreasing in 2024 by 58%, to the 0,49% of the GDP, due to a decrease in the growth of the Transaction Volume, that counted only 2 billion E-CNY in the first half of 2024.

Number of Transactions is poorly reported, only presented in 2023 for 18,87 million transactions, an average of 1,19 transactions per wallet in 2023, a number below both the

National Average Transaction per wallet in End-2022 and Mid-2023, respectively by 81% and 70%.

Dalian	2022	2023	2024	Average	YoY Growth 22/23	YoY Growth 23/24
Average Spent per Wallet	9719,63	664,56	87,5	3490,56	-93%	-87%
Average Spent per Transaction		1107,58				
Average Transactions per Wallet		1,19				

Table 15 Dalian's Average Spent per Wallet, Average Spent per Transaction and Average Transactions per Wallet 2022-2024. Author's elaboration

Average Spent per Transaction is below the national average for End-2022 by 19%, but above it for Mid-2023 by 17%. Average spent per wallet is decreasing dramatically from 2022, which was above the national average, to the first half of 2024 which is the lowest of all the cities considered in this research.

Dalian is one of the poorest cities for data disclosure. In 2023, compared to Changsha, the nearest as per resident population, performed better considering that Changsha had 1,35 on Average Transactions per Wallet but with 7 million more wallets. But the Average Spent per Wallet trend is not promising for User Engagement neither for lower-value purchases nor for higher value ones.

Pertaining Coverage didn't share as much as the other cities analyzed till now. It implemented the possibility to recharge bus cards in 2022. In 2023 stated that the E-CNY ecosystem included 51000 application scenarios and 18000 merchants accepting, numbers considerably below other cities' coverages. In 2024 application scenarios increased to 63000.

Policies and Activities are published since 2021. Promotions cover sport activities like "2021 Dalian Sports Carnival" "2021 大连体育嘉年华" distributed 1,8 million E-CNY in digital Red Packets to encourage sport spending, a promotion replicated in 2022 increasing to 150 million E-CNY. Promotions in shopping districts for festivals are various as for instance "2021 Dalian Shopping Festival 0411 Consumption Season" "大连购物节·0411 消费季", or "Dalian Rural Consumption Festival" "大连乡村消费节", "Dalian International E-Commerce Festival" "大连国际电商节", with JD.com and Alibaba contributing to the event counting for 30 million E-CNY sales. State-owned enterprises invited hi-tech zone works for dining and internal consumption scenarios.

Loans are aimed to companies in general, primarily to farmers for rural development and digital economy counting 3,02 billion E-CNY direct subsidies. In 2023 carried out the first "green loan" for 20 million E-CNY to support a company involved in waste management and pollution control to improve its services and finance new projects.

Funds count 4,5 billion E-CNY public welfare funds, comprising a talent fund for 45000 individuals into technology and innovation research. In 2023 initiated the Dalian Housing Provident Fund Management services. In 2024 also Dalian, following Shenzhen's example started implementing prepayment funds through smart contracts in dining, education and fitness industries.

Dalian was the first city to implement E-CNY for tax payments to citizens and companies, custom duty payments and non-tax revenue payment for education and other public services. In 2023 is registered the first cross-province corporate tax payment in E-CNY by a Suzhou-based construction company.

In Dalian a E-CNY based platform for digital B2B settlements has been opened in 2021 to ensure transparency, efficiency and security in digital B2B payments. Moreover, it pioneered E-CNY for port logistic services to streamline port-related payments and enhance efficiency for settlements related to shipping industry in an initiative called "Internet + Port and Shipping Services" "互联网+港航服务".

Dalian after a sustained start in Average Transactions per Wallet, witnessed a hard braking not only for daily purchases, never truly promoted at least not as the other cities did, but for funds, subsidies, loans and services to companies. For what concerns its innovative projects, never reported quantitative results nor subsequent updates, thus making impossible to address quantitative results.

- *Chengdu*

Chengdu Municipality didn't report quantitative data from 2021 till present. What I came in possess through my research limits in qualitative data, i.e. Coverage and Promotional Activities.

Pertaining coverage, Chengdu implemented E-CNY payments in public transportation such as metro, buses, ride-sharing and taxis.

Policies and Activities are reported starting from 2022. Concerning Promotions, Chengdu introduced the "520" (meaning "I love you" "我爱你") E-CNY digital consumption vouchers for a total of 1,6 billion E-CNY distributed through JD.com, Vipshop, and Meituan, with discounts on retail, dining and travel, activity replicated in 2023 with the "618" (June 18th) Shopping Festival, granting 16000 of digital coupons applicable online. For 2022 Spring Festival Chengdu issued 200 million E-CNY in digital Red Packets to be used at the local shops.

Chengdu implemented rural revitalization activities granting loans -a common policy in all "10+1" pilot- thus without reporting any related quantity.

Prepaid funds through smart contract are carried in Chengdu for educational services.

Chengdu implemented like all the other pilot cities, the possibility for enterprises to pay corporate taxes and VAT, and for citizens to pay personal income tax, enhancing digitalization of public service sector. In 2023 payments for taxes and social security exceeded 1,1 billion E-CNY.

During the World University Games Chengdu distributed E-CNY hard wallets to athletes and tourists for shopping and public transport. 3600 users registered and performed transactions through these hard wallets.

Chengdu is following other cities in the "10+1" pilot strategy, i.e. granting rural revitalization loans and loans for companies in general, prepayment funds through smart contracts, tax payments for companies and citizens, digital red packets and online coupons. This city didn't bring forth a city specific project beside the significant promotions through e-commerce. This is why it would have been really useful to possess some quantitative data to make fairer comparisons among the cities.

- *Hainan*

Hainan was the first entire province opening to the pilot. 21-22 Data were promising showing a great increase in Wallets Opened, Number of Transaction and most of all in Transaction Volume.

Hainan	YoY 2021-22	YoY 22-23	YoY 23-24
Wallets Opened	142%		
Number of Transactions	105%		
Transaction Volume	530%		

Table 16 Hainan's Wallets Opened, Number of Transactions and Transaction Volume YoY 21-22. Author's elaboration.

Wallets reached the 86% of the total population and the Transaction Volume the 0,81% of the GDP, however showing a 404% growth from 2021.

Hainan	2021	2022	Average	YoY Growth 21/22
Average Spent per Wallet	285,40	624,32	454,86	119%
Average Spent per Transaction	83,95	423,92	253,94	405%
Average Transactions per Wallet	3,399	1,47	2,436	-57%

Table 17 Hainan's Average Spent per Wallet, Average Spent per Transaction and Average Transactions per Wallet 2021-2022. Author's elaboration

Unfortunately, data are missing for 2023 and 2024. In 2021 Average Transactions per Wallet presented the second highest value in the whole "10+1" pilot, that decreases in 2022 because the number of wallets issued increases more than the number of transactions, maybe result of ineffective promotions. Another explanation can be found in a shift in promotional activities toward higher value purchases. Transaction Volume increases a lot and this is also reflected in the Average Spent per Wallet and in the Average Spent per Transaction. These ratios are far below the national average but higher than the ones of the other cities for the same year.

Pertaining Coverage, Hainan island's transportation systems adopted E-CNY payments in 2021. At the same time, it expanded to commercial retail sector with 1200 merchants and in duty-free shopping sector. In the same year E-CNY was implemented in Hainan schools to pay tuition fees and staff payroll.

Policies and Activities started being reported in 2021. As per the Promotions, digital Red Packets are issued to encourage consumer spending in tourism, retail and dining, a practice pursued by all pilot cities. Of this sort we can cite the "E-CNY, Wherever I travel" "数字人民币天涯任我游" in Sanya which granted 10 million E-CNY in lottery tickets. Another promotional evet issued 10 million E-CNY in vouchers to boost household appliances purchases during National Day holiday. The province in 2022 issued additional 100 million E-CNY in vouchers as a stimulus to internal demand into retail, dining and duty-free shopping mostly in the cities of Haikou, Sanya, Danzhou, Qionghai and Ding'an. the total 2022 promotional activities contributed to 480 million E-CNY in consumption and 82000 transactions. In 2023 and 2024 kept distributing vouchers for duty-free shopping, supermarkets, home appliances and e-commerce.

In 2022 BOC Hainan Branch issues the first loan for corporate financing of 43 million E-CNY. BOC Sanya Branch another one of 150 million E-CNY in the same year.

Pertaining subsidies Sanys's government issued 1 million E-CNY for the purchasing of electric vehicles with E-CNY.

Prepayment funds through smart contracts were active also in Hainan, not many specifications on those, beside the supervision activities through the program "Yuan Manager" "元管家" to further safekeep consumer funds.

Of notice, in 2023 People's Insurance Company of China (PICC) integrated E-CNY as a payment option for insurance premiums. In 2024 Hainan Agricultural Reclamation Group issued a 1 billion E-CNY bond with a 2,5% to implement rural revitalization projects.

Hainan government did China's first fiscal allocation, transferring 1 million E-CNY to the local meteorological bureau. In between 2022 and 2023 implemented the E-CNY payment for non-tax revenue collection, registering 234 million E-CNY paid by a logistics company.

Promotional activities were mainly focused to dining, retail and duty-free shopping. 2022 result show an average of 5853 E-CNY per transaction, thus a trend toward mid- high- value purchases rather low-value ones. However, it was the first to apply an ATM currency exchange machine to exchange foreign currency cash into E-CNY, similar to the ones provided during the 2022 Beijing Winter Olympics. Despite the appearance of a daily purchasing tool strategy, E-CNY might be considered in Hainan more a tool for high-value loans and tax payments, and maybe in the future for bonds. In fact, Averages show a trend toward more expensive transaction in 21-22 but not having data for 23-24 it leaves this as an assumption, toward a framework more similar to Suzhou and Shenzhen.

- *Xi'an*

Xi'an is the most consistent city for data disclosure. Wallet growth decreases through the years, but is might due to the fact that were already the 211% of the resident population in 2021. The Number of Transactions is growing but not performing as good as Hainan even though has more population, with a slight lower growth for 22-23. Transaction Volume had almost a stop in 21-22 but increased remarkably in 22-23 by 133%, keeping a 75% for the first half of 2024. The

Xi'an	YoY 2021-22	YoY 22-23	YoY 23-24
Wallets Opened	-10%	-19%	-34%
Number of Transactions	80%	72%	
Transaction Volume	12%	133%	75%

Table 18 Xi'an Wallets Opened, Number of Transactions and Transaction Volume YoY 21-22 to 23-24. Author's elaboration

ratio of Transaction Volume to the GDP kept around 0,5% beside 2022 where it dropped by 89%. Notably has grown to 1,96% of the GDP for the first half of 2024.

Xi'an	2021	2022	2023	2024	Average	YoY Growth 21/22	YoY Growth 22/23	YoY Growth 23/24
Average Spent per Wallet	210,33	27,49	412,95	822,66	368,36	-87%	1402%	99%
Average Spent per Transaction	375,00	54,85	427,8		241,32	-85%	680%	
Average Transactions per Wallet	0,561	0,50	0,97		0,676	-11%	93%	

Table 19 Xi'an Average Spent per Wallet, Average Spent per Transaction and Average Transactions per Wallet 2021-2024. Author's elaboration

Average Spent per Wallet, Average Spent per Transaction and Average Transaction per Wallet are all below far below the national average, however regaining conspicuously in 2023, which still is below other Cities' Averages in the same year beside Changsha's Average Spent per Wallet and the Average Spent per Transaction.

Xi'an trend is showing that a lot of people made a lot of wallets but then again didn't use them. In 2022 increased transactions for lower-value goods or services, and in 2023 increased both the values and the transactions made by the wallets. User base is saturated and the city is trying to root engagement either with low and mid value transactions.

Reports on Coverage started in 2021. Xi'an government started implementing E-CNY payments in 14th National Games Village, underlining another "10+1" trend to implement E-CNY in official sporting competitions. Moreover, it was the first city in China to initiate E-CNY payment in taxis, though starting with only 10 taxis. Between 2022 and 2023 expanded to the metro-system. Use case scenarios counted to 729800 in 2023, counting for retail services, public transportation, tax payments, loans, utility payments and salary disbursements. Merchants accepting E-CNY counted 221000 in 2024, surpassed by Shanghai, Suzhou, and Qingdao.

Policies and Activities also started in 2021. Promotions in 2022 regarded public demonstrations in night markets, digital Red Packets to be used for daily necessities physically or on Meituan and JD.com, in order to accelerate post-pandemic recovery. In 2022 PBOC Xi'an branch and Xi'an Financial Work Bureau launched the "E-CNY Xi'an pass" "数字人民币西安通" an information hub platform on E-CNY to enhance information asymmetry, streamline the adoption, divulge promotion and services.

Loans emerged in 2021 through rural financing, in the form of small agricultural loans, continued also in the following years.

In 2023 Xi'an Municipal Housing and Urban-Rural development Bureau introduced E-CNY payments for residential maintenance fund management, further digitalizing the system to users.

Tax-payments and housing provident funds through E-CNY in Xi'an were implemented in 2023, later compared to other cities.

Despite being the most complete city pertaining quantitative data, Xi'an wasn't as communicative for qualitative ones. Its strategy has been the same as the other "10+1" pilot cities beside the information platform for which however we do not have data on how much it was practically useful. Promotions through digital Red Packets and vouchers has been less present than other cities, that might explain why wallets decreased every year. 2024 data would be useful to understand whether Xi'an approach confirmed more effective in User Engagement and not a simple effect of wallets decrease, even in consideration to the other two Averages, both rapidly increasing over the years, possibly for a shift in user behavior toward services offered.

- *Qingdao*

Regarding Qingdao only Transactions Number (7,85 million) and Transaction Value (28,5 billion E-CNY) for 2022 are disclosed. The Volume to GDP counts for only the 0,019% the lowest of the whole pilot, followed by 2022 Xi'an performance that however regained the next year. The Average spent per transaction is also the lowest of the "10+1" pilot with 36,31 RMB, followed by Xi'an that again regained in 2023.

As per Chengdu we will mainly focus to the qualitative data comment to try to better shape the situation in the largest city of Shandong Province.

Regarding Coverage, public transportation integrated E-CNY payments in 2022 implementing also the "1-Cent Bus Fares" as in Shenzhen. Hard-wallet and NFC can be used (for now only in Metro line 4) to take the metro even without internet or battery. In 2023 expanded E-CNY for Electronic Toll Collection (ETC) in parking lots and in toll stations, the sole in the "10+1" pilot to grant this transportation payment service. In 2023 counted 600000 application scenarios and 450000 merchants accepting.

Policies and Activities started in 2022. In that year promotions followed pilot's general directions: lotteries, sports vouchers and digital Red Packets on shopping venues and during

festivals like the “Qingdao International Beer Festival” “青岛国际啤酒节” for 10 million E-CNY, consumption projects in collaboration with Meituan and JD.com. Since 2021 Qingdao promoted the “Qing Carbon Walk” or “Green Carbon Walk” “青碳行” (Qing “青” literally means green, and is the first character of the name of the city “青岛”, Green Island, resulting in a wordplay comprising the city and the environmental intent of the project), a platform in which registered users can redeem carbon reduction credits for E-CNY, encouraging sustainable behaviors in transportation. By 2024 the platform registered 2,6 million users, a carbon reduction of 70000 tons of CO2, issued 5 million E-CNY in digital Red Packets and 20 million E-CNY in low-carbon benefits like offsetting costs for bus and metro tickets.

Prepaid funds through smart contracts have been implemented also in Qingdao in fitness and education sector.

PBOC Qingdao branch in collaboration with the Qingdao Municipal Taxation Bureau processed city’s first E-CNY export tax refund for a total of 48 million E-CNY. Companies can seamlessly pay corporate income tax since 2022. Noteworthy China Merchants Bank used E-CNY to pay 200 million in taxes. Tax payments and social insurance payments are available also for residents, but no further specification has been made on the matter.

In December 2023 Qingdao Shengtai Feng International Trade Co. Ltd. Made the first cross-border E-CNY payment in northern China equal to 40,99 million E-CNY in oil and gas trade. Cross-border services are implemented just as in Shenzhen for Hong Kong, Macau and Taiwan visitors facilitating cross-border payments, payrolls, and property transactions.

These Policies and Activities seem to count less on vouchers and Red Packets, just as Xi’an. The really low Average Spent per Transaction might lead assumptions on low-value purchases for daily activities, also in consideration to the really broad coverage, the third in the whole pilot. “Qing Carbon Walk” platform project sustain this inference. However, policies are also tending toward corporate high-value tax payments and expensive cross-border settlements that would most probably increase Average Spent per Wallet and Average Spent per Transaction.

- *Shanghai*

Shanghai has been by far the less sharing city in data disclosure and in sharing of promotional activities. A city that could have had great potential thanks to its population, its technology and innovation, and its GDP to become the center of the E-CNY pilot.

Regarding Coverage, data only report that in 2024 Shanghai could count on 1,9 million merchants accepting E-CNY and 1,4 application scenarios from public services to retail and e-commerce.

Pertaining Policies and Activities began in 2021. Digital Red Packets promoted E-CNY in shopping malls and department stores for in-store use. Internal consumption is encouraged also through vouchers and discounts to be used on Meituan, like for the "2022 Shanghai Digital Life Festival" "2022 上海数字生活节" and the "55 Shopping Season" "五五购物节". Vouchers were distributed in 2022 also to stimulate hotel and tourism market in the city, thus without specifying the entity. 5 million E-CNY of discounts were allocated in Shanghai sport venues in 2023 to boost sport-related consumption in the city. In Shanghai, like in the most of the other cities, lotteries are employed as a mean to familiarize citizens with E-CNY payment methods. Its effectiveness isn't proved, and intuitively will not attract long-term users. In 2024 Bank of Communications patrocinated the "BOCOM Benefit Season" "交行福利季", an event to promote digital E-CNY in travel, dining, shopping and cultural tourism collaborating with more than 6500 stores across the city, online platforms like Ctrip, Jiu Shi Sports and Yanyi Live.

E-CNY cross-border trade began in 2023 with settlements for precious metal and crude oil transactions. In addition, Shanghai's Pudong Area performed the first cross-border service trade settlement between an Indonesian airline and a COMAC Finance Limited subsidiary.

In collaboration with China Baowu, Shanghai, as Shenzhen, applied smart contracts in supply chain finance automating transactions between suppliers and buyers.

Noteworthy, in 2024 Shanghai reported the city's first E-CNY money laundering case in which the criminal withdrew 123000 RMB through multiple E-CNY Category four wallets linked to accounts used to make telecom frauds and gambling, reporting that is only one of a kind that counts a total volume of more than 10 million E-CNY. This report raised some concerns on the Category four anonym wallet, calling for enhanced KYC and AML methods for E-CNY wallets.

Shanghai has the most merchants accepting after Shenzhen, and the broadest use case scenarios. Vouchers, Red Packets, and lottery promotions are present but in a smaller portion than other cities. Beside the "BOCOM Benefit Season" and other scattered retail consumption related promotions, Shanghai seems more oriented toward cross-border and cross-regional E-CNY projects, citing also projects regarding capital markets but without further delve into specifications.

- *Changsha*

The capital of Hunan Province in 2021 opened 34 million wallets, more than triple of its resident population, behind only Shenzhen that however has 7 million more inhabitants. Wallets decreased progressively through the years but keeps to 214% of the population.

Changsha	YoY 2021-22	YoY 22-23	YoY 23-24	YoY 21-23
Wallets Opened				-34%
Number of Transactions	172%	57%		327%
Transaction Volume	63%	64%		167%

Table 20 Changsha's Wallets Opened, Number of Transactions, Transaction Volume YoY 21-22 to 23-24. Author's elaboration.

As per the Transaction Volume it began with a slow start that kept growing through 2022 and 2023 by 63% and 64%.

Number of Transactions, despite the 2022 acceleration, seems to slow down the pace in 2023 but still keeping it above 2021 launch performance.

Changsha	2021	2022	2023	2024	Average	YoY Growth 21/22	YoY Growth 22/23	YoY Growth 21/23
Average Spent per Wallet	150,00		235,56		192,78			57%
Average Spent per Transaction	5080,40	95,10	174,06		1783,18	-98%	83%	-97%
Average Transactions per Wallet	0,576		1,35		0,965			135%

Table 21 Changsha's Average Spent per Wallet, Average Spent per Transaction and Average Transactions per Wallet 2021-2023. Author's elaboration

We can observe that Changsha in 2021 opened a lot of wallets but that slightly more than half made a payment, and some of those made high-value payments. The average spent per transaction dropped significantly in 2022, probably due to the fact that the same promotion wasn't active no more.

2023 data can be only compared to End-2022 and Mid-2023 national ratios and resulting far below the average in all three of them, but decreasing the distance in Mid-2023 to -93% in Average Spent per Wallet, -81% in Average Spent per Transaction and -66% in Average Spent per Wallet.

Despite the not promising overview, it's one of the best performing cities in 2023 behind Xiong'an, and proportionally slightly worse than Dalian, but better than Xi'an in User Engagement. All three cities taken in consideration in 2023 perform better in the first two ratios than Changsha.

Regarding Coverage Changsha has been reserved, sharing only that had 160000 accepting merchants in 2022 and extended E-CNY payments for public transport. In 2023 tried to expand toward universities, promoting the usage in campuses with workshops and distributing Red Packets to students.

Policies and activities started being reported in 2021. Promotions consisted in E-CNY payment demonstrations in commercial areas like Wiyi Square, explaining key advantages to end users and merchants. In 2022 Agricultural Bank of China (ABC) and ICBC offered discounts at restaurants and supermarkets for payments with E-CNY. In the same year Meituan offered cashback for eco-friendly purchases. Kaifu district granted 1,5 million E-CNY in Red Packets, of which 400000 thousand distributed to healthcare workers, encouraging consumption and support post-pandemic economic recovery. In 2023 the city patrocinated the "Changsha's E-CNY Consumption Festival" "长沙市 4000 万元数字人民币消费节" unique activity in the pilot, in which 40 million E-CNY in vouchers and discounts were distributed to be used in retail, dining, transport and tourist venues. Other discounts in supermarkets and reductions in metro fares continued in 2023. In 2023 and 2024 Qingyuan street, Tianxin district, Kaifu district, Huaye Lake Community and Furong plaza kept advancing E-CNY awareness activities which highlight on E-CNY payment conveniences and educating against potential scams, which happened in 2022 with the promotion of fraudulent E-CNY hard wallets. In 2024 implemented E-CNY in sports lottery, a legal form of betting in China.

Subsidies range from machinery manufacturing, digital economy and rural revitalization. Changsha County in 2022 lent 3 million E-CNY in loans to sustain SME resilience. In 2023 the County issued 10 million E-CNY in consumer subsidies for housing, automobile purchasing and retail consumption. Additional subsidies were issued in the same and

following year in form of Red Packets to offer financial assistance to low-income and elderly residents.

E-CNY tax payments are made available for residents since 2021, the earliest in the whole pilot, but there has been no further update on the matter.

Liuyang, a city under the Prefecture of Changsha, and Tianxin District initiated in 2022 a payroll pilot for the public sector in which 10 government institutions in the sole Liuyang adhered. The project was kept and expanded in 2023.

Changsha seemed to has had a fire start in 2021 that resulted in a false start in 2022. In 2023 is trying to reshape its policies and consumer engagement of wallets that were already issued, in activities that stem below the average of the other similar cities and same year performers. The city reported the highest amount of awareness activities in 2023 and 2024 which could have contributed to the 1,35 Average Transactions per Wallet in 2023, that even if low is the second best performing in the "10+1" pilot after Xiong'an. Average Spent per Wallet and Average Spent per Transaction confirm in 2023 a shift in the strategy more toward daily use than financial support and facilitated services for companies, as instead protracted in Suzhou, Hainan and Qingdao. 2024 data would be useful to understand the effectiveness of this shift.

3.3 Beijing 2022 Winter Olympics

From February to March 2022 Beijing and Zhangjiakou hosted the Winter Olympic Games. E-CNY pilot was tested in the venues where both Chinese citizens and foreign visitors could use to make transactions. Foreign visitors could pay through cash, Visa and E-CNY via the newly issued E-CNY App, e-ink card, or bracelets containing E-CNY hardware, like a sort of hard wallet. Mu Changchun in a webinar with The Atlantic Council stated that domestic users adopted more soft wallets while foreign users more hard wallets or bracelets. Special ATMs were also stationed to exchange E-CNY and RMB, and visitors could buy E-CNY using a foreign card.[210]

[210] Atlantic Council, *A Report Card on China's Central Bank Digital Currency: The E-CNY*, 2023; Mu (2022) op. cit. p.182; Al Jazeera, *At Olympics, Beijing Sees Chance to Sell World on Digital Yuan* 2022. Consulted last 20/9/2024; Reuters, *Around 300 Million Digital Yuan Used Every Day at Olympics, PBOC Official Says*, 2022.

E-CNY has been used to make more than 2 million RMB of payments per day covering the seven major scenario areas and hosting three large-scale pilot events, totaling 403000 use case scenarios as for instance hotels, ski resorts, local transportation, shopping centers and cultural spots.[211] Unfortunately no precise data on wallets issued have been published, neither on the number of transactions, nor the specific promotional activities implemented.

Securities Daily reported a total transaction volume of 9,6 billion E-CNY during 2022 Winter Olympics, a remarkable number that however doesn't fit with Mu Changchun words stating "I have rough idea that (there are) several, or a couple of million RMB (yuan) of payments every day, but I don't have exact numbers yet".[212] So an inference that comprises a rage from 2 to 7-8 million E-CNY per day, for seventeen days of the 2022 Winter Olympics plus ten days of 2022 Winter Paralympic Games, i.e. from 54 to 189-216 million E-CNY in total.[213]

2022 Olympic Games revenues counted 15,39 billion RMB, of which 3,78 billion comes from the international market development and TV rights, another 480 million RMB in interests, rate cards and asset disposal, no tickets revenue due to COVID restrictions, so a total of 11,13 billion RMB in market development revenue. In this simple theoretical assumption E-CNY could have counted from 0,4 to 1,9% of the total Transaction Volume, instead of the 86% resulting from the assumption made borrowing Securities Daily's data.[214]

Although hard wallets were available to be obtained and used anonymously, three US senators urged U.S. Olympic Committee to prohibit American athletes from using E-CNY, citing privacy and security concerns like transaction monitoring and collection of personal information. United Kingdom and Canada followed up in cautioning their athletes for the potential privacy risks.[215]

Official declarations, news reports, and data report on the Winter Olympics E-CNY pilot have been quite limited. Data sharing has been scarce, and it hasn't had much resonance moving forward. A lack of data publication doesn't necessarily mean that the project was a failure, but Chinese authorities usually don't shy away from reporting successes. Concerns

[211] Zhengquan Ribao (证券日报), *E-CNY "10+1" Pilot Likely to Expand, Full Rollout Still Faces Obstacles* (*数字人民币试点 10+1"有望扩围 全面铺开尚存阻力*), 2022. Last consulted 22/9/2024.

[212] From the Atlantic Council Webinar on Digital Currencies, see *Reuters* above note 210.

[213] https://en.wikipedia.org/wiki/2022_Winter_Olympics.

[214] https://english.beijing.gov.cn/latest/news/202305/t20230508_3089511.html consulted last 20/09/2024

[215] Al Jazeera, *At Olympics, Beijing Sees Chance to Sell World on Digital Yuan* 2022. Consulted last 20/9/2024

about foreign accusation on monitoring and privacy violations, like the ones just stated, might be another reason for the lack of disclosure.

Conclusions

This thesis firstly aimed at raising awareness on CBDCs, its specifications of technical and theoretical framework， addressing potentials and risks for users, monetary policy and financial stability. Then, it followed providing a practical case study on the Chinese CBDC to observe whether the characteristics theoretically entrenched in a CBDC are mirrored into the Chinese one. The reasons behind the issuance of a CBDC are common but the importance attached to each characteristic is country specific. These can be found in: enhancing payment efficiency, promote financial inclusion, digitalization of services, keep up with other countries' innovations, streamline government payments directly to citizens, ease tax payments procedures, respond to cryptocurrencies and private companies issued currencies.

In the case of China, context is already imbued of digitalization of daily activities. Fast and cheap payments are already available and well rooted, E-CNY could only find space through merchants, being completely free-of-use also by their side. E-CNY can enhance financial inclusion of the unbanked population or for foreigners, thus opening one or more wallets through the App. E-CNY is then seen as a tool to improve internal demand, a tool to limit cryptocurrency activities, the third pole that will balance Alipay and WeChat duopoly, the instrument to improve monetary policy, to fight tax evasion, to exercise more control over the population also reshaping social credit system, and finally as the solution to overcome or dodge the dollar to become the international CBDC.

The E-CNY pilot is still really young. The goals are numerous, and results are not immediately attainable as Rome wasn't built in a day. TPS are still limited by technology, but with great potential. WeChat and Alipay will not be outclassed, at least for now, and E-CNY is instead acting as a complementary service. Crypto might be banned but they will keep circulate. Unbanked people might be opening E-CNY wallets but aren't using them, and foreigners are directed toward Alipay and not E-CNY platform. E-CNY might be the solution to avoid US sanctions and internationalize E-CNY but, beside mBrigde project, is still very far from that, either for retail, B2B, wholesale and even for remittances.

Notably, Chinese academic literature and Officials publications seem to don't address financial stability risks as much as ECB or Bank of Italy are, and didn't publish any detailed report on the matter. The lack of distinct regulations on E-CNY, the scarcity of publications either alone or in collaboration with international organizations beside BIS, the opacity in transparency for data collection and sharing contribute to the reasons why E-CNY is still little used and PBOC must address on that, as well as a clear refund practice whenever subject to fraud through E-CNY.

E-CNY total Transaction Volume has almost reached the trillion euros, almost billion Total Transactions and 120 million Wallets opened. If we take a closer look at the "10+1" pilot and if we assume, as officials state, E-CNY primary as a tool for daily consumption activities, then "10+1" pilot cannot be considered a success.

As per the wallets, every city beside Hainan province (86%) opened more Wallets than the resident population, ranging from Xi'an's 104% to Dalian's 318%, attesting a total average (considering the cities where data is available) of 1,83 wallets per person, of which we don't know how many are actually active.

Number of Transactions are counted in millions with Changsha and Xi'an as the best performers with cumulative Total Transactions counting respectively 83,7 million and 47,12 million transactions. The number keeps increasing in all pilot cities every year, with Suzhou growing by 700% in one year as best performer, or decreasing the growth but keeping the pace as Changsha in 22-23 with 57%. However, this data is humbled when compared to the total amount of Wallets. The best performing city in terms of Average Transactions per Wallet (per year) has been Xiong'an with 7,26 in 2023. Other cities report Suzhou and Shenzhen as the worst performers oscillating respectively from 0,04 and 0,05 to 0,24 for Suzhou in 2023, re-calibrating the 700% YoY growth. Xi'an and Changsha report 0,97 and 1,35 Transactions per Wallet per year and are between the best. Common Average Transactions per Wallet assesses around 1,3. These results are far from WeChat and Alipay performances, which compute these numbers per day basis not per year.[216]

Nonetheless, Transaction Volume has been increasing in all pilot cities every year, from 12% in Xi'an 21-22 (then improved in 133% in 22-23), to 530% in 21-22 Hainan or 1047% in 22-23 Suzhou. When these numbers are compared to the Wallets and to the Number of

[216] https://expandedramblings.com/index.php/wechat-statistics/; https://www.ledgerinsights.com/ant-alipay-ipo-a-rosy-picture-with-a-few-questions/

Transactions, i.e. Average Spent per Wallet and Average Spent per Transaction we notice that figures are above or much above what is considered the average daily consumption. All figures presenting Average Spent per Wallet and Average Spent per Transaction toward lower-value activities like Xi'an in 2022 and partly Hainan, then increased by several times toward higher value activities. The sole exception is Changsha which is reporting the reverse trend. Suzhou is reporting incredible five digits Averages, with a Total Volume that exceeds its annual GDP. Xiong'an, despite being taken as the best performer for user engagement, reports the second highest amounts, followed by Dalian, Hainan and Xi'an. The overall Average Spent per Wallet is 11505 E-CNY, while the overall Average Spent per Transaction is 86000 E-CNY. Such an equivalent further underlines that the E-CNY platform is not oriented toward daily consumption, at least for now.

Therefore, analyzing the Average Transactions per Wallet we notice that many wallets are opened, but they are little to no employed. The Average Spent per Wallet and the Average Spent per Transactions show a marked tendency toward mid- to high value purchases instead to lower ones, further sustaining an E-CNY platform not for daily consumption.

Pertaining Coverage, Promotions, and Activities research evinced that multiple strategies are followed. One coordinating the pilot that bifurcates itself, the second is pursued by each city developing innovative solutions with E-CNY. Here we notice that the "Common Strategy" has been much more efficacious toward companies than consumers.

The Common Strategy has two sides. The first if following Coverage, attempting to expand use case scenarios, merchants accepting, broadening the service to citizens in public transport, cultural spots, elderly care, utility payments, and tax payments. One kind of common promotion was Public Sector's E-CNY payroll, in Shenzhen and Suzhou mostly, even though the efficacy difficult to assess, because employees could potentially immediately transfer their E-CNY wage into WeChat, Alipay or bank account. More common promotions consist of discounts and Red Packets to be used in shopping districts, supermarket and malls, during seasonal festival or commercial initiatives; vouchers are granted for targeted consumption like performing arts, cinema and sport. Chengdu, Shenzhen and Xiong'an pursued these activities, also in collaboration with e-commerce platforms like Meituan and JD.com to promote E-CNY for online purchases. Some cities like Shanghai and Qingdao didn't follow as much this promotional strategy.

Originally, this kind of promotions were aimed to foster post-pandemic recovery and consumption, while inducing users to open E-CNY wallets to make purchases, and then it continued till present. They seem to be consumer-oriented, toward low-value daily activities, as also the broad Coverage might persuade to think. However, the results either national or "10+1" pilot illustrate a different trend, clearly not linked to this kind of consumption. This is might due to ineffective promotions unable to exert user retention after the wallet opening, a dubious approach of users toward the platform, either due to the privacy concerns, and well-established habitudes, or again because there's another orientation strategy being implemented. All these three explanations might be true but is impractical to make assumptions to the entity of each.

The other, more successful, side of the Common Strategy is oriented toward micro enterprises, SME and Corporations. Funds and loans for SME, first were aimed to post-pandemic recovery, and then to sustain E-CNY businesses into more stable demand. Suzhou, city also very active in the other side of the strategy, reported tens of thousands of loans for more than 150 billion E-CNY. Shenzhen follows with 616 million E-CNY for micro and small enterprises, then Xiong'an, Dalian and Hainan issuing subsidies, loans and funds for companies. To be fair, subsidies were also oriented toward citizens, with subsidies to buy vehicles like in Shenzhen, and Changsha, electric vehicles as in Suzhou and Hainan, and for housing as again in Changsha. Interestingly, many loans were appointed for rural revitalization, found in Xiong'an, Xi'an, Chengdu, Shenzhen, Suzhou and Dalian, trying to associate fundings with digitalization of the rural areas. Tax payments are present for citizens but mostly for companies, from corporate tax and non-tax payments, custom-duty payments, mostly in Shenzhen, Hainan and Dalian. Smart contracts are employed in prepayment fund management for dining, education and fitness activities, whereas Shenzhen and shanghai applied them for B2B supply chain automation.

Despite the Official stated direction, Coverage and Promotions aimed to low-value and frequent purchasing aren't taking hold. The Common Strategy is more successful and aligned toward enterprises' financing than retail consumption, whereas promoted activities failed to retain users after the wallet opening.

Beside this strategy, some cities pursued *ad hoc* activities that if get a foothold might be implemented nationally. Shenzhen promoted an additional location-oriented strategy which encouraged cross-border consumption and tax payment facilitations in E-CNY to Hong Kong visitors, or citizens living in Shenzhen. Shanghai also promoted cross-regional and cross-

border projects for precious metal and oil settlements in E-CNY. The city also performed the first cross-border service trade settlement in E-CNY with an Indonesian Airline. Dalian developed a B2B platform to make B2B payments through E-CNY and implemented another one to provide port logistic services with E-CNY. Xiong'an implemented an E-CNY Government Procurement Cloud Platform, improving to more transparent contracts and reducing financing costs. Qingdao developed a unique solution, the "Green Carbon Walk" to foster the use of public transportation through E-CNY while pursuing sustainable behaviors in transportation. In Hainan the first E-CNY bond has been issued, opening E-CNY to further uses. Moreover, the same province integrated E-CNY as a payment option for insurance premiums.

These specific projects confirm E-CNY platform as performing more in innovative digital solutions of government services, and for local, cross-regional and cross-border business relations than to daily consumption tools initiatives.

Observing the data, the Averages, the strategies implemented in Coverage, Promotions and Activities, is evinced that E-CNY for now is a platform for enterprises funding and digitalization of services. Policies are successful for high value purchases even though PBOC yearn E-CNY to be a platform for lower-value purchases and frequent transactions, pursuing it to become an everyday utility as WeChat and Alipay.

As deduced in the second chapter, in order accomplish such a goal Promotions and Activities have to be mixed to educational ones. Awareness-raising efforts has to be sided with mid- to long-term solutions instead relying solely on immediate discounts. For instance, greater investing in prepayment funds or convenient subscriptions, such as those seen in Qingdao public transportation, can provide more protracted benefits. The Government must ensure users of the convenience of this platform, being more open in the disclosure of aggregated data, as well as methods and rules beneath the securing of their consumptions data. This could enhance consumers' trust toward a secure, convenient and habitual mean of payment. In addition, this could improve international understanding and potential coordination for ulterior cross-border projects between E-CNY and other CBDCs, or to become a global example of consolidated CBDC infrastructure for other nations approaching CBDC, thus approaching its international aspiration.

Appendix

Herein the *Tables 21, 22, 23, 24* referred to the Wallets Opened, Number of Transactions and Transaction Volume of the "10+1" pilot cities from 2021 to half-2024, followed by *Table 25* displaying the ratio of the Wallets to Resident Population and Transaction Volume to the city's GDP for cities and years available.

2021	Wallet Opened (M)	Total Transactions (M)	Transaction Value (100M)	GDP (100M)	POP (M)
Shenzhen					
Suzhou					
Xiong'an					
Dalian					
Chengdu					
Hainan	3,63	12,34	10,36	6475,2	10,2046
Xi'an	27,1	15,2	57	10688,28	12,873
Qingdao					
Shanghai					
Changsha	34	19,6	51	13270,7	10,2393

2022	Wallet Opened (M)	Total Transactions (M)	Transaction Value (100M)	GDP (100M)	POP (M)
Shenzhen	28	1,29	376	32387,68	17,662
Suzhou	20,09	1,01	3400	23958,3	12,911
Xiong'an			80	345,13	12,735
Dalian	1,07		104	8430,9	7,531
Chengdu					
Hainan	8,8	25,3	65,3	6818,22	10,27
Xi'an	24,26	27,36	63,67	11486,51	12,996
Qingdao		7,85	2,85	14920,75	
Shanghai					
Changsha		53,25	83	13966,1	10,4206

2023	Wallet Opened (M)	Total Transactions (M)	Transaction Value (100M)	GDP (100M)	POP (M)
Shenzhen	28,25				17,7901
Suzhou	29,16	8,08	39000	24653,4	12,958
Xiong'an	1,64	11,9	144,8	412,7	1,20544
Dalian	15,8	18,87	209	8752,9	7,539
Chengdu					
Hainan					
Xi'an	20,47	47,12	148,2	12010,76	13,0782
Qingdao					
Shanghai					
Changsha	22,5	83,7	136	14331,98	10,5131

*2024(first half)	Wallet Opened (M)	Total Transactions (M)	Transaction Value (100M)	GDP (100M)	POP (M)(2023)
Shenzhen	35,88				17,7901
Suzhou	29,43		50000	12059,4	12,958
Xiong'an	1,64	18,3	188	n	1,20544
Dalian	24		230	4262,9	7,539
Chengdu					
Hainan					
Xi'an	13,59		260	5717,47	13,0782
Qingdao					
Shanghai					
Changsha					

2021	Shenzhen	Suzhou	Xiong'an	Dalian	Hainan	Xi'an	Qingdao	Changsha
Wallets/POP					36%	211%		332%
Transaction V/GDP					0,160%	0,533%		0,38%
2022	**Shenzhen**	**Suzhou**	**Xiong'an**	**Dalian**	**Hainan**	**Xi'an**	**Qingdao**	**Changsha**
Wallets/POP	158,53%	156%		14%	86%	187%		
Transaction V/GDP	1,16%	14%	23%	1,234%	0,81%	0,058%	0,019%	0,594%
YoY Growth W/P					141%	-11%		
YoY Growth TV/GDP					404%	-89,111%		54,642%
2023	**Shenzhen**	**Suzhou**	**Xiong'an**	**Dalian**	**Hainan**	**Xi'an**	**Qingdao**	**Changsha**
Wallets/POP	158,80%	225%	136%	210%		157%		214%
Transaction V/GDP		144%	16%	1,20%		0,704%		0,37%
YoY Growth W/P	0,17%	45%		1375%		-16%		
YoY Growth TV/GDP		918%	-32%	-2,753%		1112%		-37,775%
2024	**Shenzhen**	**Suzhou**	**Xiong'an**	**Dalian**	**Hainan**	**Xi'an**	**Qingdao**	**Changsha**
Wallets/POP	202%	227,12%	136%	318%		104%		
Transaction V/GDP		91%	10%	0,493%		1,96%		
YoY Growth W/P	27%	0,93%	0%	52%		-34%		
YoY Growth TV/GDP		-37%	-33%	-58,93%		177,84%		

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Glossary

ABC= Agricultural Bank of China

AE= Advanced Economy

AML/CFT= Anti Money-laundering and Counter Terrorism Financing

BCEAO = Banque Centrale des États de l'Afrique de l'Ouest

BIS= Bank of International Settlements

BOC= Bank of China

BOCOM= Bank of Communications

BoI= Bank of Italy

BS= Balance Sheet

CB= Central Bank

CBDC= Central Bank Digital Currency

CBN= Central Bank of Nigeria

CCB= China Construction Bank

CFA= Chartered Financial Analyst

CIB= China Industrial Bank

CMB= China Merchants Bank

CPIPP= Children's Personal Information Protection Policy

DC/EP= another way to say Digital Renminbi

DLT= Distributed Ledger Technology

ECB= European Central Bank

e-CFA= Digital Communauté Financière Africaine

E-CNY= Digital Renminbi

e-Krona= Digital Swedish Krona

EMDE= Emerging Market Developing Economy

e-Naira= Digital Nigerian Naira

e-Peso= Digital Uruguayan Peso

ETC= Electronical Toll Collection

ETF= Exchange Traded Fund

FPS= Fast Payment System

FSB= Financial Stability Board

ICBC= Industrial and Commercial Bank of China

IMF= International Monetary Fund

ISO20022= International Standard Organization

LCR= Liquidity Coverage Ratio

NMD= Non-Maturing Deposits

NPC= National People's Congress

NSFR= Net Stable Funding Ratio

O2O= Online to Offline

PBOC = People's Bank of China

PIPL= Personal Information Protection Law

PIPP= Personal Information Protection Policy

PSBC= Postal Savings Bank of China

PSP = Payment Service Provider

PSP= Payment Service Provider

PvP= Payment versus Payment

RMB= Renminbi

Sand Dollar= Digital Bahamian Dollar

TPS= Transactions Per Second

WEF= World Economic Forum