



Research article

Asian CBDCs on the rise: An in-depth analysis of developments and implications

David Kuo Chuen Lee*, Chia Mei Shih and Jincheng Zheng

Finance Programme, School of Business, Singapore University of Social Sciences, Singapore

* **Correspondence:** Email: davidleekc@suss.edu.sg.

Abstract: In this paper, we present an in-depth analysis of Central Bank Digital Currencies (CBDCs), focusing on their definition, purpose, design considerations and recent developments. We also delve into the potential advantages of CBDCs for Asia, such as enhancing convenience, precisely quantifying economic metrics, managing anonymity, catalyzing innovation, and promoting financial inclusion. Moreover, we examine how CBDCs can fortify monetary and fiscal policies, ensure safe distribution, reduce costs and combat corruption. We also address the risks associated with CBDC adoption in Asia and explore potential outcomes such as substitution effects, valuation fluctuations, and foreign currency dependence, while highlighting the importance of managing financial imbalances, holdings concentration and public apprehension toward digital currencies.

Keywords: Central Bank Digital Currencies (CBDCs); digital monetary system; Fintech; financial inclusion; monetary innovation

JEL Codes: E42

Abbreviations: AI: Artificial intelligence; BIS: Bank for International Settlements; CBDC: Central bank digital currency; DCEP: Digital currency electronic payment; DLT: Distributed ledger technology; e-CNY: Electronic Chinese yuan; HKMA: Hong Kong Monetary Authority; IMF: International Monetary Fund; KYC: Know your customer; MAS: Monetary Authority of Singapore P2P: Peer to

peer; RTGS: Real-time gross settlement; SWIFT: Society for Worldwide Interbank Financial Telecommunication

1. Introduction

The world of finance is undergoing a seismic shift with the advent of Central Bank Digital Currencies (CBDCs). These digital representations of traditional fiat currencies, officially issued and regulated by central authorities, are poised to redefine the very essence of money in a digital age. CBDCs could eliminate or reduce the cost of trusted third-party intermediaries in the financial system and potentially substitute traditional deposits and government bonds by offering central bank liabilities to a wider range of economic agents. Within this evolving landscape, CBDCs serve as a bridge between monetary policy, cutting-edge technology and the ever-evolving framework of financial regulations. In an era where digitalization has reshaped the way we engage with economics, CBDCs emerge as a potent tool for central banks to adapt to the rapidly evolving financial ecosystem while preserving the essential elements of monetary sovereignty and regulatory control.

We embark on an exhaustive exploration of the multifaceted world of CBDCs, offering detailed insights into their fundamental definitions, overarching goals and the intricate web of implications they cast across regulatory and technological perspectives. By delving deep into the design considerations that underpin CBDCs and conducting an in-depth analysis of recent developments, with a particular focus on the Asian region, we seek to illuminate the vast spectrum of opportunities and challenges that CBDCs present for the region. Asia, a region characterized by its diverse economic landscapes and flourishing digital ecosystems, stands at the crossroads of the CBDC revolution. In this paper, we endeavor to peel the layers and reveal the multitude of benefits that CBDC adoption can bestow upon Asia. These advantages span the realms of convenience, precision in quantifying economic productivity and money circulation, managed anonymity, safeguarding of monetary and fiscal policies, stimulation of innovation, expansion of financial inclusion, reduction in distribution costs and curtailment of corruption, thereby elevating the region's economic and social landscape.

However, as with any paradigm-shifting technology, CBDCs also harbor risks and uncertainties that must be meticulously navigated. This paper examines these potential perils, offering a nuanced understanding of how CBDCs might impact the financial and economic landscape of Asia. These risks encompass hazards associated with the potential removal of financial intermediaries, the vulnerabilities inherent in technological infrastructures, the ever-looming specter of heightened cybersecurity threats, concerns over the acceleration of bank runs, the imperative of establishing an open and secure digital infrastructure and the necessity of enhancing public digital literacy to ensure smooth adoption. Furthermore, we also explore the intricate complexities of CBDCs potentially substituting traditional deposits or sovereign bonds, the valuation premiums that might emerge during crises, the advent of CBDC derivatives, the potential for Asia's dependency on foreign currencies, concerns about financial imbalances, the concentration of CBDC holdings and the challenges stemming from limited public understanding and acceptance of digital currencies.

By embarking on this profound journey through the multifaceted landscape of CBDCs, we aim to provide policymakers, financial institutions and stakeholders in Asia with a comprehensive and nuanced understanding of the transformative potential and associated risks of CBDC adoption. Ultimately, we seek to equip the region to chart its course in leveraging CBDCs as catalysts for economic growth, financial stability and enhanced monetary policy management, thereby positioning Asia at the forefront of the dynamic 21st-century global financial ecosystem. The rest of the paper is organized as follows. Section 2 defines CBDCs and outlines their fundamental goals. Section 3 delves into the intricate regulatory and technological perspectives of CBDCs. Section 4 explores a range of factors that central banks and policymakers must carefully evaluate when developing and implementing a CBDC system. Section 5 reflects on the recent developments of CBDCs in Asia, highlighting the progress made in the region and offering insights into the challenges faced. Section 6 uncovers the risks and opportunities that the adoption of CBDCs could bring to the Asian region. Section 7 concludes the paper.

2. Definition and goal of CBDC

A CBDC is a digital form of a country's national currency that is issued and regulated by the central bank or monetary authority. Unlike cryptocurrencies like Bitcoin or Ethereum, CBDCs are typically considered legal tender and are directly issued and backed by the government, making them a digital representation of the physical currency. This concept represents a groundbreaking development in finance, offering the potential to fundamentally transform the way money is created, distributed and exchanged. While CBDCs share the commonality of being digital currencies issued by central banks, they are by no means uniform in their characteristics or objectives.¹ As central banks around the world explore the possibilities of CBDCs, it becomes evident that these digital currencies are not monolithic entities but rather multifaceted constructs that adapt to the unique needs and priorities of their respective jurisdictions. The absence of a universal definition of CBDC is a testament to the dynamic and evolving nature of this financial innovation, reflecting the complexity and diversity inherent in the world of digital currencies.

CBDCs function as a form of cash or electronic currency accessible to the public for everyday transactions and as a secure means to store value. These digital currencies act as a conduit linking conventional currencies with the digital era, seamlessly integrating the benefits of digital finance into the fabric of the modern economy. As research and practical implementation efforts advance, the Bank for International Settlements (BIS) has continually refined its definition of CBDCs to enhance the understanding of this innovative financial concept. At the forefront of CBDC research and

¹In 2020, the International Monetary Fund (IMF) provided its definition of CBDC as a novel form of currency issued in digital form by the central bank, with the primary intention of being recognized as legal tender (Tommaso Mancini Griffoli et al., 2018). In 2022, the Federal Reserve refined the concept by characterizing CBDC as a digital obligation of the central bank, specifically designed to be readily accessible to the public (Board of Governors of the Federal Reserve System, 2022). These distinct definitions highlight the multifaceted nature of CBDC and the evolving understanding of its various attributes among financial institutions and regulatory bodies.

implementation, the BIS currently recognizes a CBDC as a digital representation of a national currency, denominated in its official unit. It possesses several key characteristics (BIS, 2022):

- (i) It serves as a direct liability of the central bank, cementing its status as an official form of currency.
- (ii) It operates in tandem with physical banknotes and reserves, constituting an integral component of central bank money.
- (iii) It is accessible to the public, offered within a closed network of licensed institutions, or used for cross-border transactions and settlements.

Furthermore, the latest refinement acknowledges the potential for traditional central bank reserve or settlement accounts to be held by commercial banks and selected financial institutions at the central bank, effectively encompassing them within the purview of CBDC (G20, 2022). That said, it is noteworthy that scholars and industry practitioners have yet to reach a consensus on the precise definition of CBDC. This variability arises because CBDCs can be tailored to function as retail, wholesale or hybrid systems, with specific functionalities purposefully designed to accommodate diverse economic activities. As technology continues to advance, economic demands evolve and practical experiences accumulate, the definition of CBDC remains a fluid concept subject to ongoing discussions and refinements. These ongoing dialogues surrounding the definition of CBDC will persist as the landscape of digital currencies continues to evolve.

In several fundamental ways, CBDCs stand apart from traditional physical currency, like tangible banknotes and coins and electronic forms of money, like commercial bank deposits. CBDCs are issued directly by the central bank or government and exist only in digital form. Just like physical currency, CBDCs hold legal tender status and are accepted as a valid form of payment for all transactions within the issuing jurisdiction. However, CBDCs differ from electronic money in terms of their fundamental characteristics and regulatory oversight. While both CBDCs and electronic money exist in digital form, CBDCs are a direct liability of the central bank or monetary authority, subject to its direct control and regulation.

In contrast, electronic money, often represented as commercial bank deposits, is created through the lending and deposit-taking activities of commercial banks. The creation and management of electronic money are vested with multiple commercial banks contributing to its circulation. This non-centralization can introduce complexities and counterparty risks² that are not present in CBDCs, which are directly issued and guaranteed by the central bank, enhancing their stability and reliability within the financial system and offering the central bank more direct control over monetary policy. Furthermore, CBDCs may have specific features and functionalities, such as programmable smart contracts, that distinguish them from traditional electronic money, promoting financial inclusion and offering new possibilities for financial innovation and efficiency. It is worth noting that there are notable differences between CBDCs and electronic currency products. According to BIS (2000), electronic money products pertain to prepaid items or stored value where the available funds or value of the consumers are kept in their electronic devices. Items such as prepaid cash cards fall within this definition, while products offering electronic access to otherwise traditional payment services such as

²CBDCs eliminate counterparty risk as they are directly held and guaranteed by the central bank. In contrast, commercial bank deposits carry a degree of counterparty risk, as they depend on the financial health of the commercial bank holding the deposits.

online banking are not included. CBDC serves a wider range of purposes than e-money, as it incorporates the latter's functions and additional features.

Compared to traditional physical currencies, CBDCs introduce a higher level of traceability in financial transactions. This heightened traceability can be attributed to the digital nature of CBDCs, which inherently records and tracks each transaction within the system.³ Moreover, CBDCs present a significant advantage in facilitating cross-border transactions. They offer a standardized digital currency that transcends national borders, eliminating the need for complex currency exchange processes and the associated costs and risks. This starkly contrasts with physical currency, which requires currency exchange at uncertain rates, and electronic money which often relies on intricate cross-border banking infrastructure with corresponding transaction fees and delays. The ability of CBDCs to simplify cross-border payments holds the potential to streamline international trade and finance significantly. CBDCs can also reduce transaction costs for digital payments. By eliminating intermediaries in electronic transactions, CBDCs can make financial exchanges more efficient and cost-effective. In contrast, physical currency transactions may involve expenses related to handling, transportation and security, while electronic money transactions can incur various fees, such as service charges, foreign exchange fees and transaction fees, depending on the service provider. The cost-effectiveness of CBDCs has the potential to make digital transactions more accessible and affordable, particularly for cross-border and online payments, fostering financial inclusion and efficiency.

In the realm of CBDCs, two distinct categories have emerged, each tailored to serve specific needs within the financial ecosystem. These categories are known as retail and wholesale CBDCs. A wholesale CBDC is limited to a specific number of firms, whereas a retail CBDC is widely accessible to consumers (Auer et al., 2020). Retail CBDC is designed to cater to the needs of the public. It functions much like traditional physical currency but exists purely in digital form. It is accessible to individuals and businesses for everyday transactions, including payments, purchases and peer-to-peer transfers. This form of CBDC has the potential to safeguard the monetary sovereignty of a nation and redefine how individuals interact with money. It offers enhanced convenience and security while promoting financial inclusion by providing access to low-cost payment options and digital financial services for a broader population segment. Wholesale CBDC, on the other hand, is primarily aimed at financial institutions and large financial transactions. It is conceived as a digital instrument to optimize the efficiency and security of high-value, interbank and cross-border transactions. It aims to streamline the intricate web of financial institutions' interactions, reducing settlement times, counterparty risks and transaction costs. Consequently, this type of CBDC holds the potential to revolutionize the global financial infrastructure, making international trade and finance more efficient and secure.

The introduction of CBDCs is driven by a multifaceted set of goals and objectives, each designed to address specific challenges and opportunities within the modern financial landscape. Although the primary objective is to facilitate cash-based transactions, a CBDC could complement the central bank's monetary supply to the population and promote a more robust and heterogeneous domestic payment

³While this feature enhances transparency and aids in activities like anti-money laundering (AML) and counter-terrorism financing (CTF), it also brings about valid concerns regarding privacy. CBDC users may worry about their financial transactions being closely monitored or their financial data being exposed. In contrast, physical currency transactions offer a greater degree of anonymity, as they involve no digital records or tracking mechanisms.

infrastructure. It also opens perspectives that are not possible with traditional cash and encourages innovative developments (BIS, 2020a). In addition, CBDCs seek to promote financial integration and optimize payment systems, boosting transaction efficiency and security and reducing the cost of cross-border payments (MAS and Bank of Canada, 2019). These objectives collectively reflect the potential of CBDCs to reshape the financial future, addressing multifaceted economic challenges while embracing opportunities for progress.

In developed countries, the primary focus regarding the implementation of CBDC centers on addressing data and privacy protection concerns, as well as grappling with issues related to data ownership. These concerns stem from the burgeoning influence of financial technology (FinTech) and large tech companies, which often engage in rent-seeking behavior by accumulating vast amounts of user data. By introducing CBDCs, central banks and governments can establish a framework that ensures stringent data privacy standards, thereby safeguarding individuals' financial information and granting them greater control over their data. Additionally, CBDCs offer an opportunity to challenge the data hegemony of tech giants by providing an alternative digital payment option that respects user privacy. They also play a crucial role in facilitating cross-border transactions, a particularly valuable function for developing economies engaged in international trade. On the other hand, in developing economies, the key priorities associated with CBDC adoption revolve around enhancing payment resilience and competition. CBDCs can fortify payment systems, making them more robust and resistant to disruptions, such as those caused by natural disasters or technical failures. Moreover, CBDCs can promote competition in the financial sector by enabling smaller financial institutions and innovative startups to offer digital payment services, which can ultimately benefit consumers through increased choices and lower costs.

In summary, a CBDC is typically issued and monitored by the central bank of a country. It differs from Bitcoin, which is subject to decentralized control (BIS, 2018b). While the specific priorities for CBDC adoption may differ between developed and developing economies, the overarching potential of CBDCs remains significant. These digital currencies have the capacity to drive innovation, enhance efficiency, promote financial inclusion and stabilize economies, regardless of their level of development. Both advanced and emerging economies can harness the capabilities of CBDCs to address their unique challenges and contribute to the evolution of the global financial ecosystem.

3. The regulatory and technological aspects of CBDCs

3.1. The regulatory framework of CBDCs

The regulatory framework governing CBDCs represents a pivotal facet of their inception and implementation as it facilitates the seamless assimilation of CBDCs into established monetary and financial systems, while attending to a multitude of legal intricacies and considerations. The successful introduction and management of CBDCs hinges on the central banks, which serve as the exclusive authorities responsible for overseeing the official currency of a nation. Central banks necessitate a legal mandate that explicitly confers upon them the authority to both issue and administer CBDCs. This mandate endows them with the requisite powers to create and effectively

regulate digital currencies within the national financial ecosystem. Central banks can navigate the complexities of introducing a digital currency seamlessly by establishing the necessary infrastructure, defining the parameters of CBDC issuance and crafting robust regulatory mechanisms that promote financial stability and protect the interests of users. Moreover, this mandate ensures that CBDCs are integrated cohesively into the broader monetary and financial framework, aligning them with the economic goals and objectives of a nation.

Once central banks have firmly established their legal authority and mandate to issue and oversee digital currencies, they undertake the customary practice of granting legal tender status to CBDCs. This designation is a fundamental feature that underpins the role of CBDCs as a legitimate and universally accepted digital form of currency within the jurisdiction where they are issued. It provides the legal foundation for the use of these currencies in everyday transactions and emphasizes their importance in modernizing the payment landscape while maintaining trust and confidence in the monetary system. However, their seamless integration with existing financial systems is equally paramount, requiring comprehensive regulatory frameworks to address interoperability. This entails the seamless alignment of CBDCs with established monetary and financial systems, encompassing legacy payment systems, traditional banks and financial institutions. Such integration serves the dual purpose of facilitating a smooth transition and preserving uninterrupted financial operations. By addressing interoperability comprehensively, regulatory bodies can ensure that CBDCs harmonize effortlessly with the existing infrastructure, promoting the efficient coexistence of digital currencies with traditional financial systems while minimizing disruptions in financial transactions and services.

CBDCs represent a significant transformative force within the global financial landscape. They transcend mere technological advancements, as their creation and implementation necessitate a comprehensive regulatory framework which involves complex considerations that span across legal, economic and social dimensions. For example, Anti-Money Laundering (AML) and Know Your Customer (KYC) regulations are rigorously enforced to thwart illicit activities such as money laundering and terrorist financing. Stringent provisions for data privacy and cybersecurity are in place to protect sensitive financial data from theft and fraud. Consumer protection measures, such as dispute resolution mechanisms and safeguards against unauthorized transactions, foster trust within the CBDC ecosystem.

The regulatory framework also extends its reach to cross-border transactions by clarifying the legal status of CBDCs in international trade and facilitating regulatory cooperation among central banks or governments. Within this context, legal considerations encompass aspects such as contract enforcement, liability, taxation and property rights, collectively working to establish transparency within a wide range of contractual arrangements involving CBDCs. Lastly, the emphasis on international coordination and regulatory harmonization is a pivotal aspect of this framework. It promotes interoperability and compliance across different jurisdictions such that the CBDCs from one country can seamlessly interact with those from another country, facilitating cross-border CBDC transactions on a global scale. Such coordination is essential in ensuring that the potential benefits of

CBDCs, such as faster and more efficient international payments, can be realized without unnecessary friction or complications.⁴

3.2. *The technological framework of CBDCs*

The technological infrastructure required for CBDCs is a multifaceted ecosystem, consisting of distributed ledger technology (DLT) or non-DLT and digital wallets, among other essential components. This infrastructure is pivotal in enabling secure, efficient and transparent digital transactions while ensuring compliance with regulatory standards. It is a complex ecosystem that combines various components to ensure the secure issuance, distribution and management of digital currencies by central banks.

Blockchain or DLT lies at the core of the technological infrastructure required for CBDCs in that it serves as the foundational technology for CBDC creation and operation. A blockchain-based token has the potential to serve as an independent digital representation of the fiat currency of a country (European Parliament, 2019). These platforms provide features such as decentralized consensus mechanisms⁵, immutability of transaction records and transparency to ensure the integrity of the CBDC system while adhering to regulatory requirements and promoting trust among users. Specifically, blockchain and DLT operate on a decentralized network of nodes or validators. This decentralization eliminates the need for a single central authority, such as a commercial bank, to validate and record transactions. Instead, transactions are collectively verified by a distributed network, increasing trust and reducing the risk of manipulation or fraud. Central banks can leverage this trust to issue and manage digital currencies with confidence. Once transactions are recorded on a blockchain or DLT, they become immutable. This feature ensures the integrity of the transaction history, making it tamper-proof and transparent. Central banks can rely on the immutability of the ledger to maintain a secure and verifiable record of all CBDC transactions.

Blockchain and DLT offer a high degree of transparency. Every transaction conducted within the CBDC system is recorded on a public ledger that is visible to all participants. This transparency is crucial for regulatory oversight, as it allows authorities to monitor and audit transactions in real-time. It helps combat illicit activities such as money laundering and fraud, making CBDCs a secure and compliant digital currency option. Blockchain and DLT platforms also enable the use of smart contracts, which are self-executing contracts with predefined rules and conditions. The contracts automate various aspects of CBDC transactions, such as payment processing, settlement and regulatory compliance. By reducing the need for intermediaries and streamlining operations, smart contracts enhance the efficiency and cost-effectiveness of CBDC transactions. Moreover, privacy features can

⁴A report jointly published in October 2020 by seven central banks (i.e., central banks of Canada, the United Kingdom, Japan, the European Union, the United States, Sweden, and Switzerland) and the BIS outlined three foundational principles and four core features that are essential for any publicly available CBDC to enable central banks to achieve their public policy objectives (Riksbank, 2020).

⁵Within the realm of blockchain or DLT, a key consideration is the choice of consensus mechanism. While some CBDCs may employ energy-intensive mechanisms like proof-of-work (PoW) or more energy-efficient alternatives such as proof-of-stake (PoS) for transaction validation, others may opt for consensus models like proof-of-authority (PoA) or other tailored algorithms.

be integrated when needed. Technologies like zero-knowledge proofs and confidential transactions allow users to protect sensitive transaction details while complying with regulatory requirements. This flexibility enables central banks to strike a balance between privacy and transparency, catering to a wide range of use cases.

Blockchain and DLT are known for their robust security features. Transactions are secured through cryptographic mechanisms, making it extremely difficult for unauthorized parties to manipulate or compromise the system. This high level of security is crucial for protecting CBDC holdings and ensuring the trust of users. Moreover, blockchain and DLT platforms can be designed to be interoperable, allowing CBDCs to interact seamlessly with other digital currencies, financial systems and cross-border payment networks. This interoperability is vital for facilitating international trade and cross-border transactions, making CBDCs a practical choice for global commerce. In fact, interoperability stands as a foundational cornerstone within the infrastructure of CBDCs, underlining its paramount importance. It is instrumental in ensuring that CBDCs can be accessed and used across different digital wallet solutions and financial services, regardless of geographic borders or connectivity limitations.

Complementing the blockchain infrastructure are digital wallets, which serve as the user interface for CBDCs. These wallets come in various forms, including mobile apps, web-based platforms or hardware devices and aim to provide users with an intuitive and secure experience. To foster trust and confidence in CBDCs and safeguard users' CBDC holdings against theft or unauthorized access, these wallets must prioritize robust security measures, including encryption, biometric and multi-factor authentication, secure storage, regular updates and user education.⁶ Moreover, to prevent illicit activities, CBDC infrastructure must incorporate regulatory compliance and reporting mechanisms, including AML and KYC protocols. Scalability is also a critical aspect of CBDC system design as it ensures that CBDCs can efficiently grow alongside their user base and transaction volume without compromising performance. In fact, a scalable CBDC infrastructure is fundamental to delivering a seamless and reliable digital currency experience for users while supporting economic activities and international transactions. To achieve scalability, CBDC systems can employ strategies such as optimizing network architecture, utilizing distributed computing resources and adopting efficient consensus mechanisms.

⁶Digital wallets employ robust encryption techniques to encode sensitive user data and transaction information. This encryption ensures that any data transmitted or stored within the wallet remains unreadable and inaccessible to malicious actors. Moreover, many modern digital wallets incorporate biometric authentication methods, such as fingerprint or facial recognition technology. These biometric measures enhance security by ensuring that only authorized users can access their CBDC holdings, adding an additional layer of protection beyond traditional passwords or PINs. A crucial security feature in digital wallets is multi-factor authentication (MFA), which requires users to provide multiple forms of verification before gaining access to their CBDCs. This can include something the user knows (e.g., a password), something the user has (e.g., a mobile device), and something the user is (e.g., a fingerprint). As such, MFA significantly reduces the risk of unauthorized access. Moreover, digital wallets often employ secure storage mechanisms to protect CBDC holdings even if the device is lost or stolen. This might involve hardware encryption or secure enclaves within the device to keep CBDC keys safe from external threats.

4. CBDC design considerations

4.1. *Token-based versus account-based CBDC systems*

CBDC holds the promise of introducing a novel form of digital payment that combines the convenience and privacy of physical cash with the supervision and traceability inherent to digital currency systems. This innovative approach, often referred to as “M0.5”, retains the fundamental attributes of M0 (physical cash), including the ability to conduct offline and pseudonymous peer-to-peer (P2P) transactions. However, it also incorporates certain traceability features akin to M1, which is the broader category of digital money encompassing bank deposits and electronic payments. In essence, a well-designed CBDC can offer users the best of both worlds: The convenience and anonymity of cash and the oversight of a digital currency system. This concept is particularly transformative as it can replace the need for traditional card-based and institution-dependent payment methods, achieving a level of managed anonymity (Lee and Teo, 2020).

There are two prominent and contrasting approaches to CBDC systems, namely the token-based and account-based models. These two distinct design paradigms delve into a vast spectrum of technical intricacies, operational intricacies and regulatory nuances, collectively wielding profound influence over the functionality and widespread adoption of CBDCs. The landscape of CBDC designs is marked by trade-offs and the pivotal decision between these models necessitates a careful evaluation of specific objectives, population needs and regulatory environments, as well as weighing factors such as ease of integration, regulatory compliance and operational considerations.

Discussions regarding token-based versus account-based CBDCs have been extensively covered by various organizations, including the Bank of Canada (2018), IMF (2018, 2020), BIS (2020) and others. In a token-based CBDC system, the verification of authenticity relies on digital signatures, a cryptographic mechanism that serves as a digital fingerprint to verify the legitimacy and integrity of CBDC tokens. The digital signatures are generated using complex algorithms that create unique signatures for each CBDC token. These signatures are based on the token’s transaction details, making them highly secure and tamper resistant. When a user initiates a peer-to-peer transaction using CBDC, the digital signature is employed to confirm that the CBDC tokens being transferred are indeed genuine and have not been altered or counterfeited. This authentication process enables direct peer-to-peer transactions, wherein the payer can transfer CBDC tokens directly to the payee without the need for intermediaries such as banks or payment processors. The decentralized nature of these transactions empowers users to engage in digital currency exchanges with one another in a secure and trustless manner. In fact, the use of digital signatures not only ensures the authenticity of CBDC tokens but also guarantees their immutability and traceability on the blockchain or distributed ledger.

In an account-based system, users have accounts that are established and maintained by a central authority or a trusted third party. These accounts are linked to a balance of digital tokens or assets, and users are required to authenticate themselves using various means, such as passwords, private keys or other credentials. When a user loses its password or private key in this context, it can be a significant hurdle to access the user’s account and initiate token transfers. However, if the user can provide adequate proof of its identity to the central authority, there may be mechanisms in place for account

recovery or password reset. These processes typically involve verifying the user's identity through additional verification steps, such as confirming personal information or providing secondary authentication factors. Once identity is sufficiently established, access to the account may be restored, enabling token transfers to resume.

In sum, the choice between token- and account-based CBDC models can have significant implications for user control, security and the role of central authorities. These model differences reflect the evolving landscape of digital currencies and central bank efforts to balance security and user-friendliness. While account-based systems offer recovery options in case of lost credentials, they involve central custody of assets. As such, users do not need to manage private keys or cryptographic credentials directly. Instead, the central bank takes responsibility for safeguarding the assets and ensuring their security. This approach provides a level of familiarity and ease of use for users who may be more accustomed to traditional banking services. Conversely, token-based systems operate on a non-custodial model in that users have direct control over their assets. This implies that they are responsible for the security of their private keys; they have to carefully manage their credentials, which might entail limited options for recovery if the credentials are lost.

4.2. CBDC tiered systems

CBDCs are not a one-size-fits-all solution. According to the G20, CBDCs should serve as a guide for the assessment of different strategies by central banks (G20, 2021). These tiered systems play a pivotal role in shaping how CBDC issuance and management are structured, thereby exerting a profound influence on the dynamics of payment systems and financial intermediation. There are four primary tiers in the realm of CBDCs, namely one-tier, two-tier, hybrid-tier and multi-tier systems, each distinguished by its organizational structure and the relationships among key actors.

In a one-tier system, the central bank takes on the primary role of issuing the CBDC directly to users and overseeing all payment and circulation functions. This direct approach places full responsibility on the central bank for the issuance, distribution and management of the CBDC. While it provides the central bank with significant control, it can also be operationally intensive and may limit innovation within the payment ecosystem. Conversely, a two-tier system delegates some of the CBDC issuance and management responsibilities to commercial banks and other authorized financial institutions. These intermediaries utilize their established infrastructure and expertise to issue CBDCs that are backed entirely by central bank liabilities. This approach can help mitigate certain operational and systemic risks by introducing a layer of intermediaries into the CBDC ecosystem while maintaining a direct central bank claim.

The hybrid-tier model, on the other hand, combines elements of both the one-tier and two-tier systems. It allows for direct central bank claims on CBDCs while also permitting intermediary roles in payment processing and administration. This model strikes a balance between central bank control and leveraging the private sector's capabilities in payment services, potentially leading to increased efficiency and innovation. The multi-tier model is the most flexible, allowing for various tiers and roles to be designed based on specific requirements. This adaptability makes it suitable for addressing a

wide range of needs. However, it can also introduce complexity and challenges in coordinating among different participants.

In 2022, the International Monetary Fund (IMF) redefined a two-tier or hybrid system (IMF, 2022). Under this definition, the central bank assumes the role of the CBDC issuer, responsible for creating and managing the digital currency, whereas the private sector is entrusted with the crucial role of distribution and operational management within the CBDC ecosystem. This reinterpretation of the hybrid CBDC system introduces a fundamental shift in the traditional understanding of tiered models. That is, instead of serving as intermediaries issuing CBDCs, the private sector is primarily responsible for the efficient distribution of the digital currency and management of its operational aspects. By being the issuer of CBDCs, the central bank is directly involved in setting the standards for how digital currencies are issued, regulated and utilized in the digital payment ecosystem. This is aligned with the core principle of sovereign control over currency issuance and therefore strengthens the central bank's authority in the CBDC landscape.

The key objective behind this revised system is to foster healthy competition among authorized private-sector operators. By enabling multiple private entities to participate in the distribution and management of CBDCs, the IMF seeks to create a dynamic environment in which these operators vie to offer innovative and efficient services to users. This competition is expected to drive improvements in the overall CBDC ecosystem, potentially leading to enhanced user experiences and cost-effective solutions. In this context, the hybrid system aims to promote competition among authorized operators and prevent the concentration of systemic operational risks, thereby ensuring a dynamic and secure CBDC ecosystem. Moreover, by diversifying the entities responsible for CBDC distribution and management, this hybrid model mitigates systemic operational risks as the concentration of operational control and potential vulnerabilities are reduced. This risk reduction strategy aims to ensure the robustness and security of the CBDC system, safeguarding it against potential disruptions or vulnerabilities that could pose systemic threats.

4.3. Complexities and innovations in CBDC design

CBDC designs draw upon two fundamental cryptocurrency principles namely, Unspent Transaction Output (UTXO) and local state-based ledgers. These foundational concepts each offer distinct characteristics and benefits and play a pivotal role in shaping the structure and functionality of CBDC systems. CBDC designs can leverage the UTXO concept to enhance security, privacy and the overall functionality of the CBDC system. In blockchain and cryptocurrency systems, UTXO represents the individual units of unspent cryptocurrency that have been sent to a user's wallet or address in previous transactions and can be used as inputs in future transactions.⁷ Similarly, each

⁷In a UTXO ledger, there are no user accounts or balances, only a general ledger of outputs, spent and unspent. Tokens are stored as unspent or spent transaction outputs. Existing unspent transaction outputs (denoted by Y) must be spent entirely when used as inputs for a new transaction. Once spent, the Y output is removed from the pool of available UTXOs. If the value of the UTXO Y is greater than the amount (X) being spent in the new transaction, the difference (Y - X) will be sent back to the sender as "change." The spent output X and the change (Y - X) become new unspent

CBDC unit is considered an individual UTXO. When a user initiates a CBDC transaction, the system verifies the availability of the UTXOs associated with the sender's wallet address to cover the transaction amount. This verification ensures that the CBDC units being spent are indeed available and have not been used in previous transactions, thereby preventing double spending, a significant challenge in digital currencies whereby the same funds are used in multiple transactions simultaneously. In fact, the use of UTXO-based verification adds a layer of security to CBDC transactions, making it nearly impossible for users to manipulate their transaction history or spend the same units of CBDC more than once.

UTXO-based CBDC designs also offer enhanced privacy to users. Like individual cryptocurrency units that are separated into UTXOs in blockchain networks, CBDC units can also be separated into discrete UTXOs in CBDC systems. When a user makes a payment with CBDC, they can create a new UTXO for the recipient, effectively obscuring the transaction history and making it more challenging to trace the flow of funds. This privacy feature can be particularly important in CBDC systems, as central banks and governments often need to strike a balance between transparency and individual financial privacy. Moreover, CBDC designs that incorporate UTXO can maintain a transparent and auditable transaction history. Each UTXO is associated with a specific transaction, allowing for clear and traceable records of CBDC movement. This traceability can be valuable for regulatory and auditing purposes, as it enables authorities to track CBDC transactions while respecting user privacy and preventing illicit activities like money laundering and fraud.

In addition, CBDC systems can leverage state-based ledgers⁸ to provide real-time balance updates, support efficient smart contract execution, enable rapid transaction confirmations, maintain immutable transaction histories and enhance scalability. These advantages can contribute to the overall efficiency, transparency and usability of a central bank's digital currency, making it a more versatile and user-friendly financial tool. Specifically, state-based ledgers allow CBDC systems to provide real-time updates of account balances in that users can see their current CBDC balance immediately after a transaction is processed. Such real-time balance updates can enhance the user experience by providing instant feedback on transactions. Moreover, state-based ledgers are particularly well-suited for supporting smart contracts⁹. CBDC systems that leverage state-based ledgers can enable more efficient smart contract execution. The ledger maintains the current state of smart contract accounts and makes

transaction outputs. The original UTXO Y is marked as a spent transaction output and no longer considered unspent. Transactions are created by consuming existing unspent transaction outputs and producing new unspent transaction outputs in their place (Clifford 2019). China uses UTXO to track every transaction of e-CNY.

⁸A state-based ledger can capture the balance of the CBDC user account. It not only records token transactions but also maintains the status of smart contracts. Tokens are represented as balances within accounts, controlled by private keys and smart contracts. A distributed ledger contains local state information for specific moments in time, including balances, relevant code and other data. A private key is required to spend tokens across states and execute smart contracts. This differs from an account-based centralized model controlled by administrators with password access. However, the UTXO model can work in conjunction with the account-based centralized model. In the UTXO model, administrators holding private keys can issue passwords for users to access their electronic wallets.

⁹Smart contracts are self-executing agreements with predefined rules and conditions.

it easier to check conditions and automate contract actions without having to traverse the entire transaction history.

State-based ledgers can also facilitate faster transaction confirmations. When a CBDC transaction occurs, the system can quickly update the state to reflect the new account balances. This rapid confirmation process is especially valuable in scenarios where instant payments or settlements are required, such as in financial markets or retail transactions. To add on, state-based ledgers maintain an immutable history of transactions and the current state at any given point in time. This historical data can be valuable for auditing, regulatory compliance and dispute resolution purposes. Central banks and regulatory authorities can access a comprehensive and transparent record of CBDC transactions, enhancing the overall accountability of the system. Moreover, compared to other ledgers, state-based ledgers focus on the current state because they do not need to store the complete history of all transactions, reducing the requirements for data storage. This scalability can be advantageous as CBDC systems grow and handle a higher volume of transactions.

In essence, CBDC designs are not one-size-fits-all but can be tailored to incorporate a variety of technical features to achieve specific objectives. The different approaches that can be adopted showcase the versatility of CBDCs, allowing central banks to strike a balance between control, accessibility, privacy and decentralization based on their unique goals and regulatory frameworks. For example, two-tier, state-based ledgers can be used for intermediary-enabled Peer-to-Peer (P2P) transactions. Such a CBDC design artfully blends the oversight of the central bank with the active involvement of financial institutions such as commercial banks, which act as intermediaries to facilitate peer-to-peer (P2P) transactions. This approach ensures that the central bank maintains control over the issuance and regulation of currency while leveraging the existing financial infrastructure to enable secure, efficient and regulated P2P transfers. It offers a seamless transition from traditional banking to digital currencies, ensuring stability and regulatory compliance.

For direct P2P transactions without intermediaries, UTXO models can be used. In this approach, CBDC units are treated as discrete tokens, each with a unique identifier and value. This tokenized representation enhances the granularity and traceability of digital currency units, allowing for more precise management and tracking of transactions. Users can engage in direct P2P transactions without the need for intermediary financial institutions. They can hold CBDC tokens in their digital wallets and transfer them directly to others, enhancing privacy and decentralization. In fact, this approach aligns with the principles of decentralized finance (DeFi) and blockchain technology and grants users greater autonomy over their digital currency holdings.

In contrast, hybrid two-tier state-based architectures combine elements of both the two-tier, state-based ledgers and direct P2P transactions. Some transactions may flow through intermediaries, ensuring regulatory oversight and additional services, while others utilize the UTXO models for more private and direct exchanges. Hybrid CBDC designs seek to strike a balance between centralization and decentralization by accommodating users who seek the familiarity and services provided by intermediaries while also meeting the needs of other users who prioritize direct, privacy-enhanced transactions within a single CBDC ecosystem.

As we explore the evolving landscape of CBDC design and its various technical models, it is important to recognize that the potential of CBDCs extends beyond their foundational structures. The

integration of blockchain technology with emerging technologies such as artificial intelligence (AI), big data and the Internet of Things (IoT) within the framework of CBDCs holds immense promise. These synergies can lead to enhanced capabilities in various aspects, including AML and counter-terrorist financing (CTF) efforts. AI and big data analytics can provide powerful tools for monitoring and detecting suspicious financial activities in real-time. Moreover, the convergence of CBDCs with these technologies can spawn entirely new business models and economic paradigms. For instance, the use of AI in CBDC systems can enable advanced data analysis of spending patterns, providing valuable insights for monetary policy and economic planning. Additionally, it can offer more granular measurements of economic activity and consumer behavior, thereby facilitating more precise and responsive policymaking.¹⁰

While the choice of CBDC approaches is pivotal in shaping the foundation of a CBDC ecosystem, it is also imperative to address scalability hurdles and delineate governance frameworks for the effective development and implementation of CBDCs. Technical scalability issues in the context of decentralized ledgers and the levels of centralization or central management are persistent challenges in the world of digital currencies. Decentralized ledgers, such as those found in blockchain technology, face scalability constraints as the number of participants and transactions in the network increase. Achieving high throughput and fast confirmation times while maintaining decentralization is a complex problem. Furthermore, centralization levels or the extent of central management in a digital currency system raise questions about governance and control. Striking a balance between decentralization, which ensures transparency and security and central management, which can enhance efficiency and regulatory oversight, is a delicate task. Governance in this context involves several dimensions: The governance of blockchains by humans, the governance of humans by blockchains (through smart contracts and consensus rules), blockchains being governed by other blockchains (interoperability and cross-chain communication) and humans being governed by other humans (legal and regulatory frameworks) (McKie, 2018).

5. Reflection on recent developments of CBDCs in Asia

Central banks and governments in Asia have been closely monitoring global CBDC trends and adjusting their strategies accordingly, ensuring that the region sustains its interest and growth in this field over time. Asian central banks have been focusing on CBDCs that address cross-border payment finality, delivery versus payment settlement in securities transactions, financial system stability, high remittance costs, financial inclusion challenges, and domestic currency relevance maintenance (ADB, 2023). The progress of CBDC development varies among Asian countries, as some are actively moving towards implementation, while others are in the early stages of exploration. The year 2019 marked a significant turning point in the global landscape of CBDC research. According to a report by the Bank for International Settlements (BIS), approximately 70% of its 62 central bank members were actively engaged in researching the potential effects of CBDCs (Boar et al., 2020). This indicates a growing interest among central banks in understanding the implications and benefits of CBDC adoption.

¹⁰An illustrative example of this integration is found in China's CBDC design, which incorporates AI to analyze spending patterns.

Furthermore, two pivotal factors catalyzed a rapid acceleration in CBDC exploration by central banks. First, the outbreak of the COVID-19 pandemic in 2020 fundamentally reshaped the global economic and financial landscape. The pandemic exposed vulnerabilities in traditional payment systems and heightened the need for efficient, resilient and secure digital payment solutions. Consequently, central banks around the world began to view CBDCs as a potential tool to address these challenges. Second, the rise of stablecoins, particularly digital currencies issued by private entities, raised concerns and competition in the digital currency space. These developments further prompted central banks to expedite their CBDC explorations (Falempin, 2020).

By November 2020, the momentum had significantly increased, with approximately 80% of central banks actively investigating CBDCs (Boar and Wehrli, 2021). This marked a substantial uptick in the rate of adoption and interest in CBDCs within just a year. By 2021, the BIS reported that around 90% of central banks worldwide are actively exploring the feasibility of CBDCs. In fact, many central banks are not only conducting research but also demonstrating enthusiasm, particularly in the context of retail CBDCs with three live retail CBDCs and 28 full pilots (BIS, 2022c).

In Asia, the lack of cost-effective technology and exclusion from global payment systems have given rise to the development of innovative payment models. These circumstances have spurred local entities and authorities to take early and proactive measures to find solutions to these technological and financial inclusion gaps. The proactive steps are primarily being taken by smaller-scale national banking systems and regional governments. The benefit of conducting smaller-scale experiments lies in their capacity to decrease reliance on worldwide currencies, thus mitigating the expenses associated with adapting to emerging technological advancements. In fact, smaller economies and banking systems have found that conducting financial experiments allows them to better navigate the evolving financial landscape without being overly reliant on established global currencies.

Central banks and monetary authorities across Asia are not only conducting extensive research but also conducting concept validation and moving towards the implementation of CBDCs. Several notable examples include the CBDC pilots in Thailand and South Korea in 2020 and 2021, respectively. Furthermore, many countries in the region, including China, Cambodia, Hong Kong SAR, Singapore, Malaysia, India, Japan and South Korea, along with other regional economies, have demonstrated strong interest in exploring and potentially adopting CBDCs as a part of their financial and monetary strategies. Notably, even less developed and island nations, such as Nepal and the Marshall Islands, are actively researching, conducting feasibility studies and considering the development of CBDCs as part of their financial infrastructure. This collective interest demonstrates the widespread recognition of the transformative potential of CBDCs in addressing the unique challenges faced by these countries and highlights the significance of CBDCs in the region's financial innovation and modernization efforts.

As of now, only China and the Philippines possess the legal authority to issue CBDCs within Asia. This reflects the cautious approach taken by many Asian countries, as they carefully assess the implications, regulatory frameworks and technical infrastructure required for the successful issuance and management of CBDCs. Several central banks have started taking active steps to explore and implement these digital currencies for everyday transactions.¹¹ While real-time retail payment systems

¹¹As of July 2022, four central banks have launched a retail CBDC: the Central Bank of The Bahamas (Sand Dollar), the Eastern Caribbean Central Bank (DCash), the Central Bank of Nigeria (e-Naira) and the Bank of Jamaica (JamDex).

have existed for some time, the banking industry has not always found them to be an attractive business proposition due to intense competition (SWIFT, 2015). However, central banks have been actively advocating for the integration and expansion of real-time retail payment systems. Their aim is to create a seamless and efficient digital payment ecosystem that can benefit both businesses and consumers.

For retail CBDCs, there have been notable developments; the Bahamas and Cambodia have successfully launched retail CBDC projects, allowing citizens to use digital currency for everyday transactions. Ecuador, Ukraine and Uruguay, have completed pilot programs, indicating their commitment to exploring the feasibility of retail CBDCs and gathering valuable insights. Six other countries are in the advanced stages of piloting or conducting proofs of concept for retail CBDCs. This indicates that they are actively testing and refining the technology and infrastructure required for the adoption of CBDCs (Auer et al., 2020).

While dynamic CBDC trackers exist to monitor these developments, they may not always provide a comprehensive and accurate representation of the progress made by each country. According to SWIFT (2015), the adoption of real-time retail payment systems has been driven largely by regulatory initiatives, accounting for 73% of the adoption rate. Regulatory authorities have played a crucial role in establishing policies and standards that promote the use of these systems. One of the primary challenges hindering widespread adoption of real-time retail payment systems, including CBDCs, has been the associated costs. These systems often require significant investments in infrastructure and technology. Additionally, regulatory officers frequently need to publish policies and guidelines to encourage their use. Nevertheless, the digitization of cash through new DLT payment systems holds promise as a viable alternative. CBDC money is characterized by a token-based unit of account that only honors claims supported by demonstrated knowledge, specifically through a digital signature (Auer and Böhme, 2020). Such systems have the potential to unlock economic opportunities, particularly in developing economies, by providing efficient, secure and accessible means of digital payments. This shift towards digital currencies reflects the broader trend in modernizing financial systems and promoting financial inclusion on a global scale.

In 2014, the People's Bank of China (PBOC) embarked on a pioneering journey among central banks by establishing a dedicated research group to delve into the world of cryptocurrencies, with a particular emphasis on the feasibility of introducing a CBDC. China's initiative led to the development of the electronic Chinese yuan (e-CNY), which was officially launched in 2019. This digital currency has since been undergoing public testing, beginning in April 2020, as part of the broader Digital Currency Electronic Payment (DCEP) Project. The test's reach expanded significantly, encompassing 23 cities by 2022. As of December 31, 2021, the number of e-CNY pilot scenarios had exceeded 8.0851 million, with a cumulative total of 261 million individual wallets opened and an impressive transaction volume of 87.565 billion yuan, which is equivalent to approximately \$13.8 billion.

The e-CNY operates alongside and complements existing dominant retail payment systems in China, namely AliPay and WeChat Pay. It operates within a two-tiered system¹²: In the first tier, the

¹²This two-tiered system ensures a balance between the central bank's control over the issuance and regulation of the digital currency (in this case, the e-CNY) and the private sector's role in providing access and services to end users. It allows for a more efficient and widespread use of the digital currency while maintaining regulatory oversight and the central bank's authority over its creation and operation.

PBOC takes on the most authoritative role and has the exclusive right to create and control the e-CNY. In the second tier, private sector entities like banks, non-bank payment service providers and telecommunication operators are authorized to interact directly with end users, who are individuals and businesses that use the e-CNY for various financial transactions. These private sector participants might also offer services such as e-CNY wallets, payment processing and digital banking services to make it easier for end users to transact using the digital currency. In its current form, the e-CNY necessitates an account with a commercial bank. However, there are plans to potentially “decouple” it from the traditional banking system in the future. This would allow tourists and other users to access and use e-CNY by providing passport information (PBOC, 2021).

Moreover, China is actively working on an innovative feature that enables the use of e-CNY for transactions even when a user’s mobile device has a drained battery (Paper News, 2023). This highlights China’s continuous commitment to improving the offline capabilities of its CBDC by employing secure hardware-based methods. While the e-CNY’s design incorporates some blockchain-inspired concepts like asymmetric cryptography, traceability, immutability and peer-to-peer payments, it does not utilize blockchain technology for CBDC issuance at this stage (Gao, 2021). Instead, blockchain is employed to facilitate query services for ownership records and enhance overall system security (Yao, 2018). This approach highlights China’s selective integration of blockchain-based capabilities alongside other centralized mechanisms in its CBDC system.

Digital currencies are typically designed with functions related to assets, payments and utility. However, in the discourse surrounding digital currencies, the primary emphasis has frequently revolved around their roles as assets and methods of payment. China’s e-CNY, however, brings to light the often-overlooked utility function, introducing a new dimension to the conversation. This utility function involves the tokenization of currently illiquid goods and services. In essence, it transforms assets that are not easily tradable into digital tokens that can be exchanged. In fact, e-CNY is designed to incorporate the flexibility to support the trading of currently inactive market offerings. For example, it could be used for time-based services or as a representation of stable assets with underlying value. This flexibility allows for a wide range of potential use cases, making the e-CNY adaptable to various economic activities.

Notably, China prefers to refer to e-CNY simply as digital money rather than a digital fiat yuan. This terminology choice underscores its broader utility beyond being a direct replacement for physical yuan. In fact, one of the primary goals of e-CNY is to stimulate trade in goods and services, and its design reflects this objective. In 2023, the acceptance of e-CNY by AliPay for express payments is one practical example of this utility function in action. By promoting exchanges in new forms of commerce, the e-CNY seeks to drive economic growth through innovative trade possibilities. China’s approach to e-CNY therefore serves as a valuable case study for other countries interested in developing their CBDCs. It offers lessons in areas such as data privacy protection, system robustness, legal framework development and strategies for mass adoption. Furthermore, the exploration of the utility dimension within digital currencies presents an intriguing area for further academic and policy research, potentially unlocking additional economic value and novel use cases for CBDCs.

While China's e-CNY has gained widespread attention for its CBDC efforts, other Asian countries are also making strides in the realm of digital payments. For instance, Cambodia has developed a digital currency system called Bakong. Like e-CNY, Bakong aims to transform the way people conduct transactions and manage their finances. However, unlike e-CNY which introduces the often-overlooked utility function, Bakong, launched on October 28, 2020, takes a unique approach by utilizing Hyperledger Iroha, a closed-loop, permissioned DLT. Initiated by the National Bank of Cambodia (NBC), Bakong is a nationwide mobile application that represents a significant step in the modernization of Cambodia's payment ecosystem. Specifically, Project Bakong does not introduce a CBDC. Rather, it facilitates transactions in Cambodia Riel and the US dollar, with the aim of reducing the country's reliance on the US dollar.

The coexistence of these two authorized digital currencies within the Bakong system raises intriguing questions about substitution effects, particularly with regard to their potential impact on exchange rates. Since each Bakong token is fully backed by either the riel or the US dollar, it functions much like physical coins or banknotes stored in a wallet. This distinctive feature not only eliminates counterparty risk but also minimizes transaction costs, rendering Bakong a secure and cost-effective payment solution for users. What sets Project Bakong apart is its pioneering use of blockchain technology as the foundation for the retail payments system of a central bank. This innovation seeks to address the fragmentation in the existing payment landscape by allowing banks and fintech companies that traditionally operate independently to collaborate on a single platform in real-time. This streamlined infrastructure promises greater efficiency and convenience for users and businesses alike. Moreover, Project Bakong adopts an inclusive approach to financial access through a dual access model. First, it offers account access via a two-tier KYC system, enabling previously excluded individuals to leverage an intermediary payment hub. Second, it provides token access through direct wallet usage. By incorporating this design, the project harnesses the widespread penetration of mobile phones to promote digital payments, ultimately extending financial inclusion to a substantial portion of the unbanked population in Cambodia.

Sharing some common objectives with Bakong, the e-rupee represents India's initiative to create a CBDC, poised to revolutionize the country's payment ecosystem and promote financial accessibility. The introduction of the e-Rupee pilot by the Reserve Bank of India (RBI) in December 2022 marked a significant step towards modernizing the financial infrastructure of India. Much like other pioneering digital currency projects around the world, this initiative leverages blockchain technology to enhance transparency, security and efficiency in the payment ecosystem. In its initial phase, the retail e-Rupee pilot was rolled out in collaboration with four banks across four cities in India. In the second phase, the program is expected to expand gradually and involve more banks, cities and users, broadening the scope of digital currency adoption across the nation.

In November 2022, India initiated a wholesale CBDC trial to evaluate its suitability for settling government bond transactions. This initial trial not only laid the groundwork for efficient government bond transactions but also opened up possibilities for broader applications, such as facilitating transactions in money market funds and short-term lending, thus promoting financial market stability and efficiency. In addition, the RBI and the Central Bank of the UAE unveiled a partnership in March 2023, geared towards undertaking proof of concepts and pilot programs in the domains of remittances

and trade. This collaboration takes on particular significance as the UAE stands as India's second-largest contributor to inbound remittances, largely contributed by the Indian migrant workforce. This collaboration reflects a commitment to leveraging digital currencies to streamline cross-border transactions, reduce costs and enhance the accessibility and convenience of financial services, particularly for those sending remittances.

As we explore the evolving landscape of digital currencies, it is evident that cross-border payment efficiency in using CBDCs is a shared interest among many central banks and financial institutions (CPMI, 2020). This interest has manifested in both bilateral and multilateral experiments, including collaborations between the European Central Bank (ECB) and the Bank of Japan (BOJ) in 2019, the PBOC and the Monetary Authority of Singapore (MAS) in the same year and the Bank of Thailand (BOT) and the Hong Kong Monetary Authority (HKMA) in 2020.

The drive to enhance the efficiency of cross-border payment systems has increasingly become the primary motivation for the development of wholesale CBDCs in the past years. In a rapidly evolving digital economy, interoperability stands as the linchpin for the success of CBDCs. The economic landscape of the modern world is driven by international trade, e-commerce, remittances and the tourism industry, all of which necessitate efficient cross-border transactions. In this context, the establishment of cross-border payment centers has emerged as a strategic imperative. A design for CBDC should include interlinkage options to support cross-border operations right from the beginning (Bech et al., 2020). These payment centers aim to create an infrastructure where different CBDCs can seamlessly interact with one another, enabling businesses, individuals and financial institutions to conduct transactions efficiently and cost-effectively across borders. Such interoperability eliminates the complexities and inefficiencies that often plague international payments, such as high fees, delays and currency conversion hassles. To make this vision a reality, CBDC designs are increasingly considering interlinkage options right from the initial stages of development (Bech et al., 2020). While the potential of CBDCs for cross-border payments is promising, there is work to be done in terms of standardization, regulatory frameworks and technological infrastructure.

As we continue to explore the transformative potential of interoperability and its significance in facilitating cross-border transactions, it is worth examining real-world examples. One such example is Project Ubin, initiated by the MAS in 2016. Initially conceived to optimize domestic payment efficiency, this pioneering project sought to leverage blockchain technology to tokenize the Singapore dollar, enabling seamless interbank payments within the nation. However, the ambitions of this project did not stop at the domestic level; it evolved to encompass international payments in later phases. Remarkably, Project Ubin achieved the successful tokenization of currencies, facilitated cross-border multi-currency transfers and executed trade settlements using digital assets across diverse blockchain networks. This success story not only sets the stage for further collaborations but also paves the way for ventures like

Project Dunbar¹³ and Project Mariana¹⁴, showcasing the immense potential of combining CBDCs with decentralized finance (DeFi) technology for international settlements and trading efficiency. MAS will partner with local banks to pilot the live issuance of wholesale CBDCs in 2024, enabling instantaneous payment settlements between commercial banks in domestic transactions (Menon, 2023). In the past, the issuance of wholesale CBDCs was only simulated in test environments. With wholesale CBDCs, the processes of clearing and settlement take place concurrently within the same infrastructure. This is a departure from the current system where clearing and settlement happen on distinct systems, leading to delays in the settlement process.

Like Project Ubin, the Inthanon-LionRock project represents another remarkable endeavor, focusing on advancing cross-border payments through innovative approaches. In its initial phase, known as Project Inthanon, the BOT took significant strides by creating a tokenized version of the Thai Baht. This tokenized currency served as a testbed to evaluate its potential impact on the Real-Time Gross Settlement (RTGS) system. Building on the insights gained from this pioneering phase, the BOT and the HKMA embarked on a collaborative journey by jointly initiating Phase 1 of the Inthanon-LionRock project in 2020.¹⁵ In Phase 2, HKMA launched the Multiple CBDC Bridge Project, which aspired to explore the vast potential of DLT in the realm of CBDC applications (HKMA, 2021b). The primary objective was to enable and support multi-currency cross-border payments, acknowledging the diverse currencies involved in international trade. Furthermore, this phase delved into various business use cases within the context of cross-border transactions, encompassing both domestic and foreign currencies. Notably, this phase saw the Central Bank of the United Arab Emirates and the PBOC's Digital Currency Institute joining forces, exemplifying the global collaborative nature of these initiatives. The BIS Innovation Hub Hong Kong Center played a pivotal role in supporting this ambitious joint effort, further highlighting the significance of international cooperation in shaping the future of cross-border payments.

As we discuss the various approaches and motivations behind CBDC projects, it is intriguing to note that the development of CBDCs varies significantly between developed and developing economies. In more advanced economies like Singapore and Japan, CBDC initiatives are in their infancy and are primarily focused on wholesale use cases to ensure interoperability with existing payment systems. This

¹³Project Dunbar serves as an exemplary initiative that underscores the collaborative efforts among multiple central banks and financial institutions to transform the landscape of international settlements. This project is a partnership involving several key players, including the BIS Innovation Hub, the MAS, the Reserve Bank of Australia, Bank Negara Malaysia and the South Africa Reserve Bank. The primary goal of Project Dunbar is to create open-source distributed ledger platforms tailored specifically for international settlements.

¹⁴The collaboration among the MAS, BIS, Bank of France and Swiss National Bank in Project Mariana represents a forward-thinking endeavor that underscores the commitment of these institutions to explore innovative solutions at the intersection of CBDCs and DeFi technology. Launched in 2022, Project Mariana has a compelling objective: to investigate the potential of automated market-makers (AMMs) in enhancing the efficiency, safety and transparency of foreign trading and settlement processes.

¹⁵During this phase, participating banks in Thailand and Hong Kong were empowered to conduct peer-to-peer transactions and engage in foreign exchanges, all facilitated by cutting-edge DLT. This technological innovation not only streamlined transaction processes but also enhanced their security and transparency, marking a significant leap forward in cross-border payment efficiency.

approach ensures seamless integration with existing payment systems and aims to enhance efficiency while reducing settlement risks. However, these economies may not be in immediate need of issuing CBDCs for broader retail use. In contrast, developing countries have adopted a more enthusiastic stance towards CBDCs. Beyond the pursuit of efficiency and digital payment demand, these nations place a strong emphasis on retail CBDCs as a means to promote financial inclusion, enhance economic stability, and safeguard monetary sovereignty. As a result, they are more inclined to expedite the launch of retail CBDCs compared to their developed counterparts.

Notably, both developed and developing economies share a common motivation to explore the potential of CBDCs, recognizing the transformative possibilities they offer in modernizing financial systems and advancing economic objectives. However, despite this shared interest, a recent survey by the IMF conducted in 2022 suggests that, in the short term, only China and India are likely to issue retail CBDCs. Moreover, no country has confirmed plans to issue a wholesale CBDC in the near to medium term. This divergence in adoption timelines underscores the unique dynamics and priorities at play in the global CBDC landscape.

Table 1 depicts the key developments of CBDC in Asia and provides a comprehensive overview of the transformative initiatives undertaken by central banks across the continent. It offers a chronological account of significant milestones, regulatory frameworks, and pilot programs, showcasing the diverse approaches adopted by Asian nations in their pursuit of digital currency innovation. From the pioneering efforts of China's Digital Currency Electronic Payment (DCEP) system to Japan's exploration of a digital yen, each entry encapsulates the forward-thinking strategies driving the evolution of monetary systems in the region. This table serves as a valuable reference for policymakers, researchers, and enthusiasts alike, offering a succinct yet informative snapshot of the dynamic landscape of CBDC in Asia.

Table 1. Key development of CBDC in Asia¹⁶.

Country or region	Status	Type	Architecture	Project name
China	Pilot with China's exceptionalism	Retail and wholesale	Intermediated	e-CNY (2019) mBridge (2021)
Hong Kong SAR	Pilot (for wholesale); Research (for retail)	Retail and wholesale	Intermediated	LionRock (2017) Inthanon-LionRock (2019) e-HKD (2021) e-CNY (2021) mBridge (2021) Project Sela (2022)
South Korea	Pilot	Retail	Intermediated	Undecided (2021)
Singapore	Pilot	Retail and wholesale	Undecided	Project Ubin (2016) Project Jasper (2016) Project Dunbar (2021) Project Orchid (2021)
Thailand	Pilot	Retail and wholesale	Intermediated	Project Inthanon (2018) Inthanon-LionRock (2019) mBridge (2022)
Malaysia	Pilot	Wholesale	Undecided	Project Dunbar (2021)
Russia	Pilot	Retail and wholesale	Intermediated	Digital Ruble (2023)
Saudi Arabia	Pilot (for wholesale); Research (for retail)	Wholesale	Undecided	Project Aber (2019)
United Arab Emirates	Pilot	Wholesale	Undecided	Project Aber (2019)
Kazakhstan	Pilot	Retail	Intermediated	Digital Tenge (2021)
Japan	Pilot	Retail and wholesale	Intermediated	Digital yen (2020) Project Stella (2016)
India	Pilot	Retail	Undecided	Digital Rupee (2020)
Iran	Pilot	Retail	Undecided	Crypto rial (2022)
Israel	Pilot	Retail	Intermediated	Digital shekel Project Icebreaker (2022)
Turkey	Pilot	Retail	Undecided	Digital Turkish lira (2022)

*Continued on next page*¹⁶Sources:

1. Atlantic Council Research

2. IMF. Towards Central Bank Digital Currencies in Asia and the Pacific: Results of a Regional Survey.

3. Authors

Country or region	Status	Type	Architecture	Project name
Cambodia	Not a CBDC as it does not exchange tokens backed by central bank	Retail	Intermediated	Project Bakong (2018)
Bhutan	Development	Retail and wholesale	Undecided	Digital Ngultrum (2021)
Indonesia	Development	Retail and wholesale	Undecided	Digital Rupiah (2021)
Bahrain	Development	Wholesale	Intermediated	A trial of JP Morgan's JPM Coin digital currency system (2021)
Macau SAR	Development	Undecided	Undecided	
Laos	Development	Retail, Wholesale	Undecided	Digital Lao kip (2021)
Philippines	Development	Wholesale	Undecided	CBDCPh (2022)
Azerbaijan	Research	Undecided	Undecided	
Qatar	Research	Undecided	Undecided	
Oman	Research	Undecided	Undecided	
Jordan	Research	Undecided	Undecided	
Georgia	Research	Retail	Undecided	Digital Lari project (2023)
Vietnam	Research	Undecided	Undecided	
Nepal	Research	Undecided	Undecided	
Bangladesh	Research	Undecided	Undecided	
Maynmar	Research	Undecided	Undecided	
Lebanon	Inactive	Retail	Undecided	
Kuwait	Inactive	Retail	Undecided	
Palestine	Inactive	Retail	Undecided	Palestinian pound 2017)
North Korea	Inactive	Undecided	Undecided	

6. Risks and opportunities for CBDCs in Asia

CBDCs have emerged as a transformative force in the global financial landscape, presenting a spectrum of both risks and opportunities, particularly in the context of Asia. As governments and central banks across the continent grapple with the potential benefits of CBDCs, they are also confronted with a host of complex challenges. From fostering financial inclusion and enhancing cross-

border transactions to concerns over privacy, cybersecurity, and the displacement of traditional banking systems, Asia stands at a crossroads in its exploration of these digital currencies.

6.1. Risks of CBDCs in Asia

CBDCs carry various risks and uncertainties, particularly in the context of Asian developing countries, as they navigate the landscape of digital currencies. First, the removal or reduction of financial intermediaries through the introduction of CBDCs carries hazards and risks. Specifically, the introduction of interest-bearing CBDCs may present a challenge to traditional bank deposits, potentially leading to a crowding-out effect or prompting banks to increase deposit interest rates. As central banks can directly manage economic liquidity through modifications to the interest rate of CBDCs, the effectiveness of conventional policy tools, such as regulatory adjustments to the reserve ratios of commercial banks or changes in interest rates, may diminish and become more challenging to predict.

To mitigate these risks, non-interest-bearing CBDCs may be a preferred design choice, reducing competition with deposits and mitigating the risk of destabilizing the banking sector. However, the extent of these transition risks remains subject to ongoing research. On the other side, interest-bearing CBDCs might incentivize mass adoption in the initial phase.

Next, there are technological and cybersecurity risks since the technology underpinning CBDCs is in its early stages, with fragmented technical standards and scalability issues. The security of CBDCs is a significant concern, as any vulnerabilities could lead to substantial financial losses. The high value associated with CBDCs makes them an attractive target for hackers. It is essential to address these cybersecurity challenges by upskilling central banks and providers and developing more robust cryptographic privacy-preserving traceability. Moreover, the ease of shifting between bank deposits and CBDCs may pose a risk in times of financial instability. Transitioning from bank deposits to CBDCs during a crisis could amplify bank run risks.¹⁷

The adoption of CBDCs can face significant challenges in regions with limited network infrastructure and low smartphone penetration. Additionally, a lack of public digital literacy regarding CBDC custody technology can pose risks such as private key losses and digital currency fraud. To address these challenges, it is essential to make investments in infrastructure, establish digital literacy programs, design intuitive user interfaces and implement robust security standards. These measures collectively aim to facilitate the widespread and secure adoption of CBDCs while ensuring inclusivity for all users.

According to Allen (2000), it is crucial for central banks and governments to refrain from rapidly expanding credit. The implementation of new technology results in an uncertain future for credit levels and financial crises. As such, it is a pivotal factor to contemplate when launching CBDCs. The potential substitution of traditional deposits and government bonds by CBDCs and stablecoins has significant implications for financial markets, both domestically and globally. This shift can introduce uncertainties

¹⁷To mitigate this, specific limits on holdings, trading and conversion could be implemented. For example, to prevent large-scale shifts of funds that could destabilize the banking system, authorities could set maximum limits on the amount of CBDCs an individual or entity can hold. Restrictions on trading CBDCs could be imposed to deter excessive speculative activity and abrupt shifts in the financial landscape. To avoid a sudden rush to convert bank deposits to CBDCs, authorities might also impose conversion controls, such as waiting periods or graduated conversion rates, during periods of crisis.

for borrowers, influence exchange rates and prompt changes in the way financial institutions and governments manage their finances. It could potentially limit the lending capacity of banks and therefore have a ripple effect on the functioning of the credit market as a whole. As this transition unfolds, a vigilant approach to monitoring and adapting financial systems becomes paramount to uphold stability and mitigate potential risks. Moreover, it is essential to conduct additional investigation to determine whether this trend could improve the transmission mechanisms of monetary policy.

One notable aspect of this shift is the valuation premium that CBDCs may command during crises. In times of financial turmoil or uncertainty, individuals and entities may flock to CBDCs for their perceived safety, particularly those CBDCs that offer fixed supplies and interest payments. This surge in demand can create price premiums. It therefore becomes essential to implement mechanisms that prevent imbalances between the demand for and supply of CBDCs. Otherwise, the rush to CBDCs during crises may exacerbate financial instability. Furthermore, the rapid growth of CBDC derivatives markets introduces a layer of complexity to the financial landscape. These derivatives markets can amplify the impact of CBDCs on broader financial markets and require vigilant oversight from policymakers. Ensuring that these markets remain stable and transparent is crucial to prevent systemic risks.

A global concern arising from the adoption of CBDCs by larger countries is the potential overshadowing of digital currencies from smaller nations. This over-dependence on foreign currencies could weaken the control and effectiveness of monetary and fiscal policies for these smaller economies, leading to potential challenges in managing tax revenues and overall economic stability. Policymakers must carefully navigate these dynamics to maintain financial sovereignty. Additionally, the introduction of CBDCs needs to be accompanied by measures to address financial imbalances. There is the risk of rapid credit expansion fueled by the accessibility and ease of CBDCs, potentially inflating asset bubbles. Effective regulatory frameworks must be established to manage this relationship between credit expansion and the risk of asset bubbles, ensuring that financial stability is preserved.

The adoption of CBDCs must also consider the distribution of holdings. If CBDCs become concentrated among a limited group of wealthy individuals or entities, it can disrupt the equilibrium of the financial system and hinder financial inclusion. Therefore, setting limits on individual holdings and implementing robust KYC measures are vital steps to maintain fairness and accessibility. Lastly, in regions where the internet and financial infrastructure are underdeveloped, the promotion of CBDC adoption is a complex undertaking. It requires comprehensive public awareness campaigns and educational initiatives, particularly targeting the elderly population who may be less familiar with digital financial systems. Moreover, to prevent scams and fraud, robust safeguards need to be established within the CBDC ecosystem.

In sum, the transition to CBDCs and stablecoins represents a profound transformation in the financial landscape. To navigate this shift successfully, it is imperative to maintain a vigilant approach, adapt regulations and invest in public education to ensure the stability and inclusivity of future financial systems.

6.2. Opportunities for CBDCs in Asia

CBDCs offer several transformative opportunities to address the unique challenges faced by both developing and advanced economies in the Asian region. For developing countries in Asia, CBDCs serve

as a beacon of hope for enhancing financial inclusion. These digital currencies enable individuals to engage in peer-to-peer transactions without requiring formal bank accounts or even access to the internet. This accessibility extends far beyond the reach of traditional banking systems, making financial services available to previously underserved populations. Moreover, CBDCs hold the promise of reducing the substantial costs associated with the issuance, printing, distribution and storage of physical cash. By minimizing the reliance on paper money, CBDCs have the potential to curb corruption and counterfeiting risks, safeguarding the financial integrity of these emerging economies. In advanced Asian economies, CBDCs herald a new era in cross-border payments and settlements. With their efficiency and speed, CBDCs have the potential to surpass traditional payment systems, facilitating seamless and rapid international transactions. This can greatly benefit the global businesses and financial institutions that operate in these economies, streamlining their operations and reducing transaction costs. Additionally, CBDCs can offer precise insights into informal economic activities that often go unrecorded in formal financial systems, thereby enhancing the tracking and understanding of economic productivity.

CBDCs also strike a delicate balance between privacy and anonymity, aligning with evolving regulatory frameworks and citizens' concerns about data protection. They can be designed to ensure the privacy of users' online activities while maintaining transparency in their actions. This unique feature positions CBDCs as a viable solution for governments in Asia striving to protect the privacy of their citizens' data and adhere to international data protection laws. Furthermore, CBDCs play a pivotal role in safeguarding monetary and fiscal policies in the region. They can prevent the infiltration of non-fiat electronic currencies that could threaten the autonomy of domestic currency. This is especially crucial for regions like Macau SAR, which relies heavily on its currency's stability due to its status as a major gambling center. Macau SAR seeks to utilize CBDC to fight money laundering and tax evasion. By providing a secure and controlled digital payment infrastructure, CBDCs reduce the risk of destabilizing influences from external currencies.

As catalysts for innovation, CBDCs stimulate collaboration and entrepreneurship in the financial sector. Leveraging DLT and smart contracts, they reduce trust costs and foster new ventures. This innovation extends to the creation of token-based CBDCs that can power decentralized finance, offering more stability and trust than existing stablecoins. Moreover, CBDCs encourage interoperability between existing payment systems and public blockchain networks, creating fertile ground for entrepreneurial opportunities and employment. To add on, financial inclusivity emerges as a paramount opportunity unlocked by CBDCs, which fundamentally prioritize inclusivity by empowering individuals to engage in peer-to-peer transactions devoid of any prerequisites such as formal banking institutions, the necessity for bank accounts, or even the luxury of internet connectivity. This accessibility is particularly beneficial in regions grappling with limited or underdeveloped banking infrastructure.¹⁸ CBDCs bridge the divide, extending financial services to marginalized populations, thereby fostering greater economic participation and empowerment. Inclusivity is therefore a fundamental aspect of CBDCs.

Moreover, CBDCs provide a safer distribution channel compared to private payment systems that may underinvest in security. By offering a secure and controlled payment infrastructure, CBDCs

¹⁸For instance, countries like Russia and Iran are actively developing CBDCs to circumvent sanctions imposed by the U.S., reducing their dependence on the U.S. dollar.

mitigate the risk of cyberattacks and abuse of power by private money issuers. For example, China's e-CNY extends its reach to retail outlets issuing e-wallets, fostering competition in the payment service sector. Lastly, the issuance of CBDCs reduces significant costs associated with physical cash and coin management. The 2023 currency operating budget of the United States is \$931.4 million¹⁹. The costs of printing, storing and managing physical currency are substantial, and a portion of this currency is withdrawn from circulation annually due to loss or damage. CBDCs promise to minimize these costs, resulting in substantial savings for governments and central banks.

In sum, CBDCs are poised to reshape the financial landscape of Asia, offering a wide range of opportunities and solutions to the diverse challenges faced by the economies in the region. From enhancing financial inclusion and revolutionizing cross-border payments to ensuring privacy, safeguarding monetary policies, stimulating innovation and reducing costs and corruption, CBDCs stand as a pivotal force in shaping a more inclusive, efficient and secure future for financial systems across Asia.

7. Conclusions

The trajectory of CBDCs unfolds as a pivotal chapter in the transition toward digital economies. These innovative currencies hold the promise of streamlining financial transactions, enhancing security and promoting financial inclusion. Notably, Asian governments have taken proactive steps to stay ahead in this digital revolution. Cambodia, China, Thailand and Singapore have emerged as trailblazers, leading the way by accelerating the development of digital infrastructure, digital asset supervision, CBDC issuance and the associated financial architecture. Before delving into the realm of CBDC adoption, it is imperative to address key considerations. These encompass assessing the demands of the digital economy, establishing clear goals, strengthening the digital financial infrastructure and fostering open and constructive discourse. The path to successful CBDC implementation is influenced by a multitude of factors, but one determinant of success stands out: Strong public-private collaboration. The cooperative efforts of government entities and the private sector are poised to play a pivotal role in the success of CBDC initiatives. Central banks ought to enhance communication with industry partners, investigate viable alternatives and progressively advance the piloting and implementation of CBDCs in a timely manner based on demand.

Critical to the success of any CBDC system is the evaluation of interoperability before its launch. Interoperability ensures that CBDCs can seamlessly interact with one another and with existing financial systems, facilitating cross-border transactions and international trade. While strong national policies have spurred CBDC pilots and rollouts in several countries, it is important to acknowledge that nascent technologies may require intermediaries and cross-border interactions to achieve mass adoption, akin to the staged progression seen in bilateral or multilateral trade agreements. An array of potential focus areas presents itself on the horizon. These encompass the exploration of global stablecoin frameworks, the development of multilateral platforms and the integration of CBDCs into the broader digital financial ecosystem. These initiatives hold the promise of addressing cross-border payment challenges without compromising the minimum supervisory and regulatory standards necessary to maintain monetary and financial stability.

¹⁹https://www.federalreserve.gov/faqs/currency_12771.htm

To ensure universal success, these initiatives should prioritize financial inclusion and sustainability. Integrating CBDC endeavors with existing payment systems and other digital currencies can promote financial accessibility and contribute to a more sustainable financial ecosystem. Analysts believe that an interoperable protocol will be the driving force behind borderless global commerce, as the multifaceted nature of the global financial system makes it too complex for a single currency replacement. In this dynamic landscape, continuous research remains a cornerstone for optimizing CBDC designs by harnessing the benefits of new technological advances. Central banks are increasingly tasked with persistent CBDC enhancement, the exploration of future plans and the revision of implementation strategies. Countries are showing a strong willingness to learn from one other and to collaborate, working together to foster inclusive finance and reap the full benefits of CBDC adoption.

Undoubtedly, digital finance is the harbinger of a future with profound impact. As nations prepare for international regulatory alignment, consensus-building and unified standard-setting, the only path forward lies in understanding the technology, learning from deployment experiences, continuously re-evaluating regulatory frameworks and adapting to the ever-changing dynamics of the digital financial landscape. In doing so, it is essential to acknowledge that CBDCs also introduce new risks and challenges that demand careful management. The benefits must demonstrably outweigh the drawbacks to ensure the success of CBDC initiatives. As unforeseen dangers and complexities continue to emerge, persistent research and evaluation efforts are indispensable. Well-designed CBDCs have the potential to heighten transparency, bridge the digital divide, reduce transaction fees and broaden access to trade and financing opportunities.

The pervasive influence of fintech has set the stage for financial inclusion, with remaining challenges primarily centered on education, collaboration, infrastructure development, capacity building, resource allocation and financing. The importance of pre-CBDC capacity building, including the upgrading of communication networks and the enhancement of fintech literacy, cannot be overstated. This is crucial to drive sustainable digital economic expansion supported by a robust CBDC infrastructure. Moreover, given the digital economy's energy consumption and associated emissions, the consideration of green technology and sustainable financing merits careful deliberation. As the digital financial landscape evolves, ongoing research into CBDCs is not only expected but essential. The unknown risks and intricacies that continue to emerge underscore the importance of a continuous and adaptive approach to CBDC development and implementation. Central banks must constantly reassess their regulatory frameworks and implementation strategies to respond to emerging risks and complexities.

In sum, the path to realizing the full potential of CBDCs is one marked by challenges and opportunities, requiring diligence, collaboration and adaptability. As we navigate this transformative terrain, the goal remains clear: To harness the power of CBDCs to foster a more inclusive, efficient and sustainable digital economy.

Use of AI tools declaration

Tool Name: ChatGPT

Mode of Usage: Assisting with literature review and draft preparation.

Information Location: Various sections throughout the manuscript.

Conflict of interest

All authors declare no conflicts of interest in this paper. Most of the materials referenced in this paper are from the report “Recent Central Bank Digital Currency Developments in Asia and Their Implications” (ADB, 2023), of which the main author of the report is the first author of this paper.

Reference

- Allen F (2000) Financial Structure and Financial Crisis. Manila: Asian Development Bank. Available from: <https://www.adb.org/sites/default/files/publication/157203/adbi-rp10.pdf>.
- Asia Digital Bank (ADB). 2023. Recent Central Bank Digital Currency Developments in Asia and Their Implications. Asian Development Bank. <https://www.adb.org/publications/central-bank-digital-currency-developments-asia-implications>
- Auer R, Böhme R (2020) CBDC Architectures, the Financial System, and the Central Bank of the Future. Available from: <https://cepr.org/voxeu/columns/cbdc-architectures-financial-system-and-central-bank-future>.
- Auer R, Cornelli G, Frost J (2020) Rise of the Central Bank Digital Currencies: Drivers, Approaches and Technologies. BIS Working Papers. no. 880. Basel. Available from: <https://www.bis.org/publ/work880.pdf>.
- Bank of Canada (2018) Should the Central Bank Issue E-Money. Working paper. Ottawa. Available from: <https://www.bankofcanada.ca/wp-content/uploads/2018/12/swp2018-58.pdf>.
- Bech ML, Faruqui U, Shirakami T (2020) Payments Without Borders. *BIS Q Rev* Available from: https://www.bis.org/publ/qtrpdf/r_qt2003h.htm.
- BIS (2018b) Central Bank Digital Currencies. Basel: BIS. Available from: <https://www.bis.org/cpmi/publ/d174.pdf>.
- BIS (2000) Survey of Electronic Money Developments. CPMI Papers No. 38. Committee on Payments and Market Infrastructures. Basel. Available from: <https://www.bis.org/cpmi/publ/d38.htm#:~:text=Electronic%20money%20products%20are%20defined,device%20in%20the%20consumer's%20possession.&text=A%20number%20of%20publications%20relating,the%20auspices%20of%20the%20BIS>.
- BIS (2020a) Central Bank Digital Currencies: Foundation Principles and Core Features. Report no. 1 in a series of collaborations from a group of central banks. Basel: BIS. Available from: <https://www.bis.org/publ/othp33.pdf>.
- BIS (2020c) The Technology of Retail Central Bank Digital Currency. BIS Quarterly Review. Basel. Available from: https://www.bis.org/publ/qtrpdf/r_qt2003j.htm.
- BIS (2022) CBDC and its associated motivations and challenges – Saudi Central Bank. Chrome Browser. chrome-extension: //efaidnbmnnnibpcajpcglclefindmkaj/ Available from: https://www.bis.org/publ/bppdf/bispap123_u.pdf.
- Boar B, Wehrli A (2021) Ready, Steady, Go? – Results of the Third BIS Survey on Central Bank Digital Currency. BIS Working Paper. No. 114. Available from: <https://www.bis.org/publ/bppdf/bispap114.htm>.

- Boar B, Holden H, Wadsworth A (2020) Impending Arrival – A Sequel to the Survey on Central Bank Digital Currency. BIS Working paper. No. 107. Available from: <https://www.bis.org/publ/bppdf/bispap107.htm>.
- Board of Governors of the Federal Reserve System (2022) Money and Payments: The U.S. Dollar in the Age of Digital Transformation. Chrome Browser. chrome-extension://efaidnbmnnnibpcajpcgclefindmkaj/ Available from: <https://www.federalreserve.gov/publications/files/money-and-payments-20220120.pdf>.
- Clifford J (2019) Intro to Blockchain: UTXO vs Account Based. 20 September. Available from: <https://medium.com/@jcliff/intro-to-blockchain-utxo-vs-account-based-89b9a01cd4f5>.
- CPMI (2020) Enhancing Cross-Border Payments: Building Blocks of a Global Roadmap. Stage 2 report to G20. BIS, Basel.
- European Parliament (2019) The Future of Money. Brussels: European Union. Available from: [https://www.europarl.europa.eu/cmsdata/190218/IPOL_STU\(2019\)642364_EN-original.pdf](https://www.europarl.europa.eu/cmsdata/190218/IPOL_STU(2019)642364_EN-original.pdf).
- Falempin L (2020) What Does COVID-19 Mean for Central Bank Digital Currencies (CBDCs)? Tokeny. 14 May. Available from: <https://tokeny.com/what-does-covid-19-mean-for-central-bank-digital-currencies/>.
- G20 (2021) Central Bank Digital Currencies for Cross-Border Payments. July 2021. Report to the G20. Available from: <https://www.riksbank.se/globalassets/media/nyheter--pressmeddelanden/nyheter/2021/report-to-the-g20-central-bank-digital-currencies-for-cross-boarder-payments.pdf>.
- G20 (2022) Options for Access to and Interoperability of CBDCs for Cross-Border Payments. Report to the G20 (2022) Available from: <https://www.riksbank.se/globalassets/media/nyheter---pressmeddelanden/nyheter/2022/rapport-options-for-access-to-and---interoperability-of-cbdcs-for---cross-border-payments.pdf>.
- GAO C (2022) The significance and impact of DCEP issuance. Institute of Internet Industry, Tsinghua University. [In Chinese] Available from: <http://www.iii.tsinghua.edu.cn/info/1059/2344.htm>.
- HKMA (2021b) Joint Statement on the Multiple Central Bank Digital Currency (m-CBDC) Bridge Project. Press release. 23 February. Available from: <https://www.hkma.gov.hk/eng/news-and-media/press-releases/2021/02/20210223-3/>.
- IMF (2020) Casting Light on Central Bank Digital Currencies. IMF Staff Discussion Note. Washington, DC. Available from: <https://www.imf.org/en/Publications/Staff-Discussion-Notes/Issues/2018/11/13/Casting-Light-on-Central-Bank-Digital-Currencies-46233>.
- IMF (2022) Towards Central Bank Digital Currencies in Asia and the Pacific: Results of a Regional Survey. IMF. Retrieved September 18, 2023. Available from: <https://www.imf.org/en/Publications/fintech-notes/Issues/2022/09/27/Towards-Central-Bank-Digital-Currencies-in-Asia-and-the-Pacific-Results-of-a-Regional-Survey-523914>.
- Lee D, Teo E (2020) The New Money: The Utility of Cryptocurrencies and the Need for a New Monetary Policy. *Disintermediation Economics*, 111–172. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3608752
- Mancini Griffoli T, Martinez Peria MS, et al. (2018) Casting Light on Central Bank Digital Currencies. IMF. Retrieved November 30, 2023. Available from: <https://www.imf.org/en/Publications/Staff-Discussion-Notes/Issues/2018/11/13/Casting-Light-on-Central-Bank-Digital-Currencies-46233>.

- MAS & Bank of Canada (2019) Jasper - Ubin Design Paper. Enabling Cross-Border High Value Transfer Using Distributed Ledger Technologies: Monetary Authority of Singapore. <chrome-extension://efaidnbnmnibpcjpcglclefindmkaj/https://www.mas.gov.sg/-/media/Jasper-Ubin-Design-Paper.pdf>.
- McKie S (2018) Blockchain Communities and Their Emergent Governance: Thoughts on Legitimacy and Narratives. Amentum. 19 November. Available from: <https://medium.com/amentum/blockchain-communities-and-their-emergent-governance-cfe5627dcf52>.
- Menon R (2023) Shaping the Financial Ecosystem of the Future—Speech by Mr Ravi Menon, Managing Director, Monetary Authority of Singapore, at the Singapore FinTech Festival 2023 on 16 November 2023. Retrieved November 29, 2023. Available from: <https://www.mas.gov.sg/news/speeches/2023/shaping-the-financial-ecosystem-of-the-future>.
- Paper News (2023) Digital RMB SIM card hard wallet function will be launched: support no electricity payment, payment only touch. [In Chinese] Retrieved September 19, 2023. Available from: https://m.thepaper.cn/newsDetail_forward_23799275.
- Pei S (2021) Building an Integrated Digital Economy: How Asia Can Continue to Thrive in the Post-Pandemic Era. ThinkChina. 16 February. Available from: <https://www.thinkchina.sg/building-integrated-digital-economy-how-asia-can-continue-thrive-post-pandemic-era>.
- People's Bank of China (PBOC) (2021) Progress of Research & Development of E-CNY in China. Working Group on E-CNY Research and Development. Available from: <http://www.pbc.gov.cn/en/3688110/3688172/4157443/4293696/2021071614584691871.pdf>.
- SWIFT (2015) The Global Adoption of Real-Time Retail Payments Systems (RT-RPS). White paper, 15. Available from: https://www.swift.com/sites/default/files/documents/swift_payments_whitepaper_realtimerepayments.pdf.
- Yao Q (2018) Experimental Study on Prototype System of Central Bank Digital Currency. Available from: <http://www.jos.org.cn/josen/article/pdf/5595>.



AIMS Press

© 2023 the Author, licensee AIMS Press. This is an open access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>).