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MONOGRAFIA DE FINAL DE CURSO

Central Bank Digital Currency and Its Implications: A Critical Review

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Advisor: Prof. Fernando Mendo

Rio de Janeiro, June 2024

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I declare that this work is my own and that I did not use any form of external help to carry it out, except when authorized by the advisor.

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Abstract

This paper provides a comprehensive comparative analysis of four CBDCs. The study examines diverse motivations, implementation strategies, design features, benefits and challenges associated with each CBDC. The motivations behind each CBDC reflect the unique economic, political and social contexts of their respective countries. The Bahamian CBDC aims to enhance financial inclusion in the country, where a significant portion of the population lacks access to traditional banking services. China's e-CNY seeks to improve payment system efficiency, provide better tools for monetary control and reduce reliance on the US dollar in international trade. The US Digital Dollar would aim to maintain the US dollar's global dominance and enhance the efficiency and security of the domestic payment system. Brazil's Drex focuses on creating a comprehensive financial ecosystem, integrating with existing systems, like Pix, to improve financial services. A common strategy observed is the use of phased implementation and pilot programs, which allow central banks to test and refine their CBDCs before full-scale deployment, mitigating risks and ensuring smoother transitions. While the potential benefits of CBDCs are substantial, significant challenges remain. Addressing cybersecurity risks and privacy concerns is crucial. Key insights from this comparative analysis include the necessity of tailored approaches for each country's specific needs, early and continuous stakeholder engagement and robust testing and iteration through phased implementation and pilot programs. The introduction of CBDCs has significant geopolitical and economic implications, with the Digital Yuan potentially reducing global reliance on the US dollar.

CONTENTS

1 Introduction

The development and implementation of Central Bank Digital Currencies (CBDCs) have become a focal point for central banks around the world. As digital currencies gain traction, countries are exploring CBDCs to enhance their financial systems, address unique economic challenges and maintain global financial leadership.

A CBDC represents a novel digital form of central bank-issued currency, distinct from physical cash or traditional reserves. It can assume various forms, ranging from a token designed to replicate digital cash to an electronic unit of account, facilitating transfers between individual accounts held with the central bank.

There are primarily two categories of CBDCs: retail and wholesale. Retail CBDCs are envisioned for use by households, businesses and the general public in their everyday financial transactions. The overarching aim is to provide every household with access to a digital incarnation of central bank-issued currency. Conversely, wholesale CBDCs are intended for interbank transactions among financial institutions, including banks and central banks. These wholesale CBDC initiatives aim to enhance the safety and efficiency of digital interbank transactions.

As such, a fundamental distinction between the two types lies in the scale of transactions they are designed to handle. Retail CBDCs would typically involve smaller-scale payments, given their role in day-to-day transactions. In contrast, wholesale CBDCs would function similarly to reserve or settlement balances held with the central bank, resulting in larger-scale transactions. Consequently, a retail CBDC would impact a broader spectrum of stakeholders, encompassing consumers,

businesses, various merchants, financial institutions and the central bank. Meanwhile, a wholesale CBDC would primarily concern a narrower subset of stakeholders.

For some countries, the development of a CBDC is driven by a desire to maintain or enhance monetary sovereignty and reduce dependence on foreign currencies. This is particularly relevant for China's Digital Yuan, which aims to reduce reliance on the US dollar in international trade and finance, thereby enhancing China's geopolitical influence. Similarly, the US Digital Dollar aims to reinforce the US dollar's position as the world's primary reserve currency.

This academic paper provides a comparative analysis of four prominent CBDC initiatives: the Sand Dollar in the Bahamas, the Digital Yuan in China, the Digital Real in Brazil and the US Digital Dollar. By examining these case studies, the paper aims to offer insights into the motivations, strategies, design features, benefits and challenges associated with CBDCs.

The Bahamas, a pioneering nation in this field, introduced the Sand Dollar primarily to enhance financial inclusion. With significant portions of its population lacking access to traditional banking services, the Central Bank of the Bahamas sought to integrate the unbanked and underbanked into the formal financial system through a secure and accessible digital currency. China's Digital Yuan, on the other hand, reflects the country's broader economic and geopolitical ambitions. By developing a CBDC, China aims to improve payment system efficiency, strengthen monetary control and reduce dependence on the US dollar in international trade.

Brazil's Digital Real initiative focuses on integrating the CBDC with its existing digital payment infrastructure, particularly the suc-

cessful Pix system. This approach aims to leverage technological advancements to enhance financial services and support economic growth. In the United States, discussions around the US Digital Dollar are driven by the need to maintain the dollar's global dominance and improve the efficiency and security of domestic payment systems.

The paper will, initially, elucidate the motivation behind this study, followed by an overview of the methodologies employed. The theoretical framework will delve into the nature of CBDCs, their anticipated benefits and a comprehensive literature review focusing on theoretical underpinnings that support the study of digital currencies. Subsequently, the paper will examine case studies from various countries, analyzing key criteria such as the motivations driving their CBDC initiatives, the strategies employed for implementation, the design features adopted, as well as the identified benefits and challenges. These case studies will provide a nuanced understanding of the diverse approaches taken globally. Furthermore, a comparative framework will be established to juxtapose these case studies, drawing out critical insights and lessons.

Therefore, CBDCs represent a transformative innovation in the global financial system, driven by diverse motivations such as financial inclusion, economic efficiency and geopolitical strategy.

2 Motivation

The motivation for this monograph stems from the rapidly evolving landscape of digital currencies and the increasing interest of central banks worldwide in developing their own CBDCs. As digital currencies become more prevalent, it is crucial to understand the varying objectives and strategies employed by different countries in their pursuit of digital financial solutions. This monograph aims to contribute with existing literature by providing a detailed comparative analysis of four prominent CBDCs, highlighting the unique motivations, design choices and implementation challenges faced by each country.

The study of CBDCs is highly relevant for economic research due to several compelling reasons. First, CBDCs have the potential to transform the financial landscape by providing a new form of money that is digital, secure and backed by central banks. This transformation could impact various aspects of the economy, including financial stability and the efficiency of payment systems.

The development of CBDCs also has important geopolitical and economic implications. China-US dynamics highlight the potential for CBDCs to reshape the global economic order.

The adoption of CBDCs is driving significant technological innovation in the financial sector. This includes advancements in blockchain and distributed ledger technology, cryptography and digital identity verification. These innovations can enhance the security, transparency and efficiency of financial transactions, fostering competition and encouraging the development of new financial products and services.

In conclusion, the study of CBDCs is not only timely but also essential for understanding the future of money and finance. By examining

the specific cases of the Sand Dollar, Digital Yuan, Digital Real and US Digital Dollar, this monograph aims to contribute to the broader discourse on digital currencies and provide valuable insights for policymakers, researchers and practitioners in the field of economics and finance.

3 Methodology

This study employs a research methodology to analyze the development, implementation and implications of CBDCs. The research approach encompasses a combination of literature review, case study analysis and a comparative approach, drawing from a wide range of sources to provide a comprehensive understanding of the subject.

The literature review forms the foundation of the research, offering a theoretical and contextual backdrop for the analysis of CBDCs. This includes an extensive examination of academic articles, working papers, and reports published by central banks, the International Monetary Fund (IMF), and other relevant financial institutions. The literature review aims to elucidate the theoretical foundations of CBDCs, their historical development, and the various motivations and challenges associated with their implementation. Sources for the literature review were primarily accessed through Google Scholar and other academic databases, ensuring a broad and robust collection of relevant literature.

The core of this monograph is a detailed case study analysis of four specific CBDCs: the Sand Dollar, Digital Yuan, Digital Real, and US Digital Dollar. Each of them examines the unique context in which the CBDC was developed, the specific design features and implementation strategies employed, and the observed benefits and challenges. They draw on a variety of sources, including official reports and publications from the respective central banks, policy documents, press releases, and news articles. This approach allows for a nuanced understanding of each CBDC's development and the factors influencing its adoption.

To synthesize the findings from the case studies, a comparative ap-

proach is employed. This involves establishing a set of criteria for comparison, such as the motivations behind CBDC implementation, the strategies and design features employed, and the benefits and challenges encountered. By comparing the four CBDCs based on these criteria, the monograph identifies common themes, divergences, and key lessons that can inform future CBDC development.

Therefore, the paper aims to provide a thorough analysis of CBDCs, contributing to the academic discourse and offering practical insights for policymakers and financial institutions. The methodology ensures that the research is grounded in both theory and practice, enabling a comprehensive exploration of the subject.

4 Theoretical Framework

Blockchain and Distributed Ledger Technology (DLT) are foundational technologies for the development and operation of CBDCs. DLT refers to a decentralized database managed by multiple participants, with blockchain being a specific type of DLT that records transactions in blocks linked in a chronological chain. These technologies offer several advantages for CBDCs, including transparency, security, and efficiency.

CBDCs are digital forms of a country's sovereign currency, issued and regulated by the central bank. Unlike cryptocurrencies such as Bitcoin, which operate on decentralized networks without central oversight, CBDCs are centralized and maintain the same legal status as physical currency. The implementation of CBDCs can vary, but they generally operate on a DLT framework that ensures all transactions are recorded in a secure and immutable ledger. This framework allows for real-time settlement of transactions, reducing the need for intermediaries and enhancing the efficiency of payment systems (SODERBERG et al., 2023).

Financial inclusion is often a key policy objective for a retail CBDC, especially in emerging and lower-income countries. A well-designed CBDC has the potential to address barriers to financial inclusion and gain acceptance as a payment mechanism for financially excluded populations. CBDCs can replicate some of the desirable properties of cash, such as access to payments without a bank account, trust associated with central bank money, low or no fees, and less stringent identity requirements for low-risk populations who struggle to obtain formal identity documentation. Despite these advantages, full compliance with financial integrity requirements remains necessary. A CBDC can

offer benefits beyond those of cash. For example, it can help develop a financial history for users, which can widen access to credit and other financial services, thus serving as a valuable entry point to the formal financial system. As a public-sector-led initiative without a profit motive, a CBDC could stimulate competition by lowering the prices of payments and financial services. Moreover, CBDCs can address the needs of remote and low-income populations not well served by the private sector by being available on various hardware devices and in offline environments (LANNQUIST; TAN, 2023).

However, Lannquist e Tan (2023) points out that a CBDC by itself is not a silver bullet for financial inclusion. It can face barriers common to digital products, such as gaps in digital and financial literacy, and access to electricity and digital networks. Therefore, a CBDC may not be the best solution for this issue in every country. Policymakers should assess a wide range of policies and initiatives, beyond CBDCs, to support this matter effectively.

A current concern regarding the introduction of CBDCs is that they have the potential to disintermediate banks by allowing consumers to hold digital currency directly with the central bank, bypassing traditional financial intermediaries. This disintermediation could lead to a reduction in the demand for commercial bank deposits, potentially impacting bank liquidity and profitability. However, it also provides an opportunity for banks to innovate and offer new financial products and services that leverage the capabilities of CBDCs (SODERBERG et al., 2023).

A significant portion of a bank's funding comes from customer deposits. If CBDCs become widely adopted, individuals and businesses might shift their deposits from commercial banks to CBDCs held directly with the central bank. This shift could lead to a reduction in

bank deposits, potentially decreasing the funds available for banks to lend out and invest. This reduction in deposits might force banks to seek alternative, potentially more expensive sources of funding. On the other hand, commercial banks play a crucial role in the economy by providing loans to consumers and businesses. With fewer deposits, banks might have less capital to lend, potentially leading to tighter credit conditions. This scenario could affect economic growth, as businesses might find it harder to obtain loans for expansion, and consumers might face difficulties in accessing credit for purchases such as homes and cars (SODERBERG et al., 2023).

In this way, to attract deposits and counteract the outflow of funds to CBDCs, banks might need to offer higher interest rates on savings accounts. This increase in deposit rates could raise the cost of funds for banks, which in turn might lead to higher lending rates. Consequently, the overall cost of borrowing could increase, impacting consumer spending and business investments. Beyond that, CBDCs also also raise concerns about financial stability. In times of economic stress or banking crises, the availability of a risk-free CBDC might lead to a rapid shift of deposits away from commercial banks to the central bank. Such a scenario could exacerbate a bank run, leading to liquidity issues for banks and necessitating central bank intervention to stabilize the financial system (SODERBERG et al., 2023).

While disintermediation poses challenges, it could also foster competition and innovation in the financial sector. Banks may need to enhance their services and offer new products to retain and attract customers. This competitive pressure could drive innovation in digital banking services, leading to improved financial products and customer experiences (KIFF et al., 2020).

To mitigate the potential negative effects of disintermediation, reg-

ulatory and policy measures might be necessary. Central banks and regulators could implement frameworks to ensure that CBDCs complement rather than displace traditional banking services. Measures could include limits on CBDC holdings or tiered remuneration systems to discourage large-scale shifts of deposits from commercial banks to CBDCs. In this way, collaboration between central banks and commercial banks is crucial for the successful implementation of CBDCs. By working together, they can develop systems that leverage the strengths of both CBDCs and traditional banking services. Commercial banks, for instance, could act as intermediaries for CBDCs, offering customer-facing services while the central bank manages the underlying digital currency infrastructure(SODERBERG et al., 2023).

Furtherore, CBDCs offer central banks new tools for implementing monetary policy. By providing real-time data on economic transactions, CBDCs can enhance the effectiveness of monetary policy measures such as interest rate adjustments and quantitative easing. Additionally, CBDCs could facilitate the implementation of unconventional monetary policies, such as negative interest rates, by allowing central banks to apply these rates directly to digital currency holdings (SODERBERG et al., 2023).

The development and implementation of CBDCs are underpinned by several theoretical frameworks that provide insight into their potential impacts and adoption. Key theories, including Monetary Theory, Innovation Diffusion Theory, and Regulatory and Institutional Theory, contribute significantly to understanding these phenomena.

Monetary Theory provides the foundation for understanding the role and function of money within an economy. Traditionally, money serves three primary functions: a medium of exchange, a unit of account, and a store of value. CBDCs, as a new form of money issued by

central banks, are poised to fulfill these roles while offering additional benefits such as enhanced security and efficiency in digital transactions. According to Friedman, the supply and regulation of money are crucial for economic stability (MANKIW, 2013). The introduction of CBDCs offers central banks a novel tool to manage monetary policy more effectively by potentially offering real-time data on economic transactions and enabling more precise control over the money supply (BORDO; LEVIN, 2017)

On the other hand, the Innovation Diffusion Theory is particularly relevant for understanding the adoption of CBDCs. The theory, introduced by E.M. Rogers in 1962, examines how, why, and at what rate new ideas and technology spread through cultures. It posits that the adoption of innovation follows a bell-shaped curve, characterized by innovators, early adopters, early majority, late majority, and laggards (DIFFUSION...,). For CBDCs, the innovation adoption process involves various stakeholders, including consumers, financial institutions, and regulatory bodies. The diffusion of CBDCs depends on factors such as perceived advantages, compatibility with existing systems, complexity, trialability, and observability (HASKELL, 2024). Understanding these factors can help central banks design CBDCs that are more likely to be adopted widely and successfully.

Regulatory and Institutional Theory focuses on the role of institutions and regulations in shaping economic and social outcomes. North (1990) emphasizes the importance of institutions in reducing uncertainty and fostering economic development. For CBDCs, regulatory frameworks play a critical role in ensuring stability, security, and trust in the digital currency system. The introduction of CBDCs necessitates a robust regulatory environment to address issues such as cybersecurity, privacy, anti-money laundering (AML), and counter-terrorist

financing (CTF). Furthermore, institutional support and coordination among central banks, financial institutions, and technology providers are essential for their successful implementation and operation (ZETZSCHE et al., 2017).

5 Case Study Analysis

5.1 The Sand Dollar (Bahamas)

5.1.1 Introduction and Background

The Sand Dollar is the CBDC issued by the Central Bank of The Bahamas (CBoB). Launched in October 2020, it stands as one of the first fully operational digital currencies globally, considered the first national retail CBDC in the world, making the Bahamas a pioneer in the digital currency space. The introduction of the Sand Dollar marks a significant step in the evolution of the Bahamian financial system, designed to supplement traditional fiat currency, enhance financial inclusion, and modernize the financial infrastructure across the Bahamian archipelago (PATRICK; LYLE, 2022).

The Bahamas consists of over 700 islands, many of which are remote and lack adequate banking services. This geographical challenge has historically limited the accessibility of financial services to many Bahamians (PATRICK; LYLE, 2022). The Sand Dollar aims to address this by providing a digital payment solution that is accessible via mobile services, thereby reaching citizens in even the most remote locations. This initiative aligns with the country's broader goal of financial inclusion, ensuring that all residents have access to essential banking services (CBOB, 2019).

The CBoB has full control over the issuance and distribution of the Sand Dollar, ensuring a regulated and secure financial environment. This centralized control helps maintain monetary stability and provides a safeguard against issues such as inflation and financial fraud. The Sand Dollar operates alongside the Bahamian dollar, maintaining

a one-to-one parity with the national currency. This ensures that the digital currency can be seamlessly integrated into the existing financial system without causing disruption (CBOB, 2021a).

The development and implementation of the Sand Dollar involved significant technological and regulatory considerations. The currency leverages advanced technology to ensure secure and efficient transactions. It utilizes mobile app-based and value card-based access methods, providing users with flexible options to engage with the digital currency (CBOB, 2019). This design consideration ensures that the Sand Dollar is user-friendly and accessible to a broad spectrum of the population, including those with lower levels of technology literacy (HAQUE; SHOAIB, 2023).

Moreover, the Sand Dollar is designed with a robust legal framework to ensure its status as legal tender. The CBoB's oversight ensures that all transactions are monitored and regulated, thereby reducing the risk of illicit activities such as money laundering. The legal framework also includes provisions for Know Your Customer (KYC) and Anti-Money Laundering (AML) compliance, ensuring that the Sand Dollar adheres to international standards of financial regulation (SINGH et al., 2023).

Therefore, the Sand Dollar is a groundbreaking initiative by the Central Bank of The Bahamas, aimed at enhancing financial inclusion, modernizing the financial infrastructure, and ensuring economic resilience. By leveraging cutting-edge technology and robust regulatory frameworks, the Sand Dollar provides a secure, efficient, and accessible digital payment solution for all Bahamians. This innovative approach not only addresses the unique challenges faced by the Bahamas but also sets a precedent for other nations exploring the potential of central bank digital currencies.

5.1.2 Motivations and Objectives

According to the CBoB (2023), the main goals of the Sand Dollar are to: i) enhance the efficiency of the Bahamian payment system by ensuring more secure transactions and faster settlements; ii) offer equal access to payment systems regardless of age, immigration status, or residency; iii) promote greater financial inclusion and cost-effectiveness, ensuring wider access to financial services throughout The Bahamas; and iv) bolster national defenses against money laundering, counterfeiting, and other illicit activities by mitigating the negative impacts of cash usage.

In this way, the Bahamas pursued the development of the Sand Dollar driven by a combination of economic, social, and technological motivations. In other words, the primary objectives behind this initiative include enhancing financial inclusion, modernizing the financial infrastructure, and ensuring resilience against natural disasters.

The geographical layout of the Bahamas, with its numerous islands, has traditionally posed significant challenges to providing comprehensive banking services. Many residents, particularly those in remote areas, have limited access to financial institutions. The Sand Dollar aims to bridge this gap by offering a digital payment solution accessible via mobile devices, thus bringing banking services to underserved and unbanked populations. This inclusivity ensures that all Bahamians, regardless of their location, can participate in the financial system, enhancing financial inclusion (BOAR et al., 2020).

The introduction of the Sand Dollar is part of a broader strategy to modernize the Bahamian financial system. By adopting a digital currency, the Bahamas seeks to improve the efficiency and security of financial transactions. The Sand Dollar leverages advanced technology

to facilitate seamless and instant transactions, reducing the reliance on cash and traditional banking channels. This modernization is expected to enhance the overall efficiency of the financial system, making it more robust and capable of meeting the needs of a digital economy (CBOB, 2019).

The country is frequently affected by natural disasters, particularly hurricanes, which can disrupt traditional banking services. The Sand Dollar aims to provide a resilient financial solution that can continue to operate even during such events. By enabling digital transactions that do not rely on physical infrastructure, the Sand Dollar would ensure that residents can still access financial services and make payments in times of crisis. This resilience is crucial for maintaining economic stability and supporting recovery efforts after disasters (CBOB, 2020c).

In this manner, the Sand Dollar is designed to meet the specific needs of the Bahamian economy. It aims to reduce the costs associated with cash handling and to improve the efficiency of government payments and social transfers. By providing a secure and convenient digital payment option, the Sand Dollar also aims to enhance the overall consumer experience and support the growth of digital commerce within the country.

5.1.3 Implementation and Features

The implementation of the Sand Dollar began with a pilot in December 2019 on the island of Exuma. This pilot was significant as Exuma's diverse population and geographic characteristics made it an ideal representation of the greater configuration of the Bahamas for testing. Prior to the pilot, a survey revealed that 93% of Exuma's residents had high access to basic bank accounts, though 17% opted not to use them due to trust issues or inconvenience. Additionally,

96% owned mobile devices, and 40% used them for financial transactions, though there was notable reluctance among older residents due to cybersecurity concerns (CBOB, 2021c).

Despite the COVID-19 pandemic disrupting the initial rollout, the pilot was extended to Abaco in February 2020 to aid in financial recovery post-Hurricane Dorian, since this island was one of the most heavily affected (CBOB, 2020a). To facilitate the use of the Sand Dollar, all Supervised Financial Institutions (SFIs) were invited to become Authorized Financial Institutions (AFIs), acting as dealers of the digital currency. The onboarding process for users involves downloading the app, submitting Know Your Customer (KYC) documents to an AFI, and uploading money to their wallets via bank transfer or cash deposit (CBOB, 2021b).

The Bahamian CBDC is accessible through multiple digital wallet options. These options include a mobile app-based wallet and a value card-based system (pre-paid cards from affiliated service providers). It is relevant to highlight that this design provides an alternative for those less familiar with technology, ensuring broader accessibility across the population (HAQUE; SHOAIB, 2023).

The Sand Dollar wallet is categorized into three tiers with different requirements and limits: i) Tier I or Basic Wallet, which does not require KYC documents, allows holding up to 500 Sand Dollars, and limits transactions to 1,500 Sand Dollars per month; ii) Tier II or Premium Wallet requires a government-issued ID, allows holding up to 8,000 Sand Dollars and has a monthly transaction limit of 10,000 Sand Dollars, and it can be linked to a bank account; and iii) Tier III or Merchant Account requires a business license and a value-added tax certificate, allows holding between 8,000 and 1,000,000 Sand Dollars with no transaction limits, and must be tied to a bank account (CBOB,

2021b). Since the Tier I eWallet only requires basic user information and contact details once the app is downloaded, it makes the threshold for joining the Sand Dollar network low. Because of that, it is ideal for tourists visiting the Bahamas (CBOB, 2023).

The CBDC is classified as legal tender in the Bahamas, operating alongside the traditional Bahamian dollar. This ensures that it is accepted for all types of transactions, from daily purchases to tax payments. The designation of the Sand Dollar as electronic money under the legal framework of the Bahamas means that its issuance and distribution are exclusively controlled by the CBoB, maintaining its integrity and regulatory oversight (CBOB, 2021a). moreover, it is designed primarily as a retail CBDC, meaning it is intended for use by the general public rather than just businesses or financial institutions. This focus on retail usage helps to enhance financial inclusion and ensures that all citizens and residents of the Bahamas can benefit from the digital currency (BILGEN et al., 2024).

This CBDC operates on a two-tiered structure, involving both the central bank and AFIs. The CBoB issues the digital currency, while private banks and payment service providers distribute it to end-users (CBOB, 2021b). This two-tiered system helps to leverage existing financial infrastructure and expertise, promoting efficiency and scalability in the distribution of the Sand Dollar (SETHAPUT; INNET, 2023).

The Sand Dollar is built on a distributed ledger technology (DLT) infrastructure, ensuring transparency and security in transactions. Although the specific type of blockchain used has not been disclosed, the DLT framework allows for a secure and tamper-proof ledger that records all transactions. To address cybersecurity concerns, the Central Bank implemented end-to-end encryption and required multi-

factor authentication for accessing wallets. All AFIs undergo rigorous third-party assessments to ensure their systems meet security standards. Additionally, the Sand Dollar is restricted to domestic transactions to mitigate the risks of illicit financial flows and fraud. This centralized governance of the ledger by the CBoB maintains the integrity and reliability of the digital currency system (SODERBERG et al., 2022).

Designed as an online CBDC, the Sand Dollar requires a secure internet connection for transactions. However, the CBoB aims to develop an offline CBDC model to ensure continuous operational availability, even during natural disasters or connectivity issues. This resilience is crucial for maintaining financial services during emergencies (GOB, 2022).

Thus, the implementation of the Sand Dollar involves a comprehensive set of features and design choices that ensure its functionality, security, and accessibility. From digital wallet options and legal tender status to a two-tiered operational structure and the use of distributed ledger technology, the Sand Dollar is crafted to meet the needs of the Bahamian population while maintaining robust regulatory oversight. These design elements position the Sand Dollar as a pioneering model for other nations exploring the potential of central bank digital currencies.

5.1.4 Benefits and Challenges

One of the primary benefits of the Sand Dollar is its potential to enhance financial inclusion across the Bahamas. By providing a digital payment option accessible via mobile apps and value cards, the Sand Dollar ensures that even those without traditional bank accounts can participate in the digital economy. This inclusion is particularly ben-

eficial in remote and underserved areas where banking infrastructure may be limited.

The Bahamian CBDC has demonstrated resilience during natural disasters, such as Category 5 hurricanes (WULFECK, 2023), by continuing to function effectively. This resilience ensures that citizens can access and use their funds even in times of crisis, which is crucial for maintaining economic stability and providing a reliable means of transaction during emergencies (MASTERCARD. . . , 2021).

The digital nature of the Sand Dollar reduces the costs associated with printing, distributing, and managing physical cash. Besides that, it facilitates quick and easy transactions for everyday use. The Bahamian CBDC became fully operational after a 10-month pilot phase, allowing all citizens and residents of the Bahamas to use the CBDC for daily transactions, tax payments, and other public payments free of charge(SODERBERG et al., 2023). This cost efficiency benefits the Central Bank of The Bahamas (CBoB) and the overall economy by streamlining the currency management process and reducing the reliance on physical cash.

Utilizing Distributed Ledger Technology (DLT) provides a secure and transparent system for recording transactions. The centralized governance by the CBoB ensures that all transactions are monitored and regulated, enhancing the security and integrity of the financial system. This transparency helps in combating fraud and money laundering activities (SODERBERG et al., 2022).

Despite its potential benefits, the adoption rate of the Sand Dollar has been lower than anticipated. As of recent reports, only 7.9% of the population have adopted the Sand Dollar, with transaction volumes and circulation also falling short of predictions (CBOB, 2023). This

slow adoption can be attributed to a lack of awareness and limited promotional efforts during the initial rollout phase.

The reliance on an online CBDC model means that a secure internet connection is required for transactions. In regions with poor internet connectivity or during network outages, this dependency can hinder the usability of the Sand Dollar. Moreover, while the current system does not support offline transactions, the CBoB aims to address this by developing an offline CBDC model (GOB, 2022).

Although the DLT framework ensures transaction security, concerns about privacy and the potential for government surveillance have emerged. Users' apprehensions regarding the transparency of their financial activities can impact the willingness to adopt the Sand Dollar. Addressing these privacy concerns through clear communication and robust data protection measures is essential for building user trust (POCHER; VENERIS, 2021).

Moreover, integrating the Sand Dollar with existing financial institutions, payment service providers, and automated clearing houses has been slower than expected. As Morales-Resendiz et al. (2021) point out, this integration is crucial for expanding the reach and utility of a CBDC, and delays in this process limit its effectiveness and acceptance among potential users.

External factors such as the COVID-19 pandemic and Hurricane Dorian have affected the implementation and promotion of the Sand Dollar. These events restricted public gatherings and promotional activities, for instance, hence limiting opportunities to introduce the digital currency to the broader population. Consequently, the initial rollout did not achieve the desired level of public engagement (CBOB, 2020b). There has been a noticeable delay in marketing and educa-

tional campaigns to inform the public about the benefits and usage of the Sand Dollar. Effective promotional strategies are crucial for driving adoption, and the lack of timely and extensive outreach has been a significant barrier (SODERBERG et al., 2022). The CBoB is now focusing on these efforts to enhance awareness and encourage broader usage (CBOB, 2023).

While the Sand Dollar offers numerous benefits, including enhanced financial inclusion, resilience during disasters, and cost efficiency, it also faces challenges related to adoption rates, technological limitations, privacy concerns, and integration issues. Addressing these challenges through targeted strategies and continuous improvement will be crucial for the Sand Dollar to achieve its full potential and serve as a model for other digital currency initiatives.

5.1.5 Current Status and Future Outlook

The Sand Dollar, launched by the CBoB in 2020 is fully operational and accessible to all citizens and residents of the Bahamas. Following a successful 10-month pilot phase, the digital currency has been integrated into various aspects of daily transactions, including tax payments and public services, at no cost to users. However, despite its successful implementation, the Sand Dollar has faced several challenges.

As was pointed out above, the adoption rates among users remain low. As of recent reports, only 7.9% of the population (CBOB, 2023) and 7% of merchants (GAM, 2023) have adopted the Sand Dollar. The transaction volume stands at approximately $1.1 million, which is significantly lower than expected (CBOB, 2023). However, despite the overall low adoption, over 50% of the adult population has set up e-wallets for the Sand Dollar. This indicates a readiness to use digital

financial services, although actual usage for transactions remains limited (GAM, 2023). To increase adoption rates, the CBoB is focusing on educational and marketing initiatives to raise awareness about the benefits and usage of the Sand Dollar. These efforts are aimed at encouraging both citizens and merchants to utilize the digital currency more actively (CBOB, 2023).

The CBoB has engaged with entities like Mastercard and Island Pay to broaden the usage of the Sand Dollar. These collaborations aim to eventually allow tourists and residents to use Sand Dollars at any domestic or global point of sale accepting Mastercard, although a timeline for these developments has not been provided (**??**).

The current Sand Dollar system supports only online transactions (GOB, 2022). The CBoB is working towards developing an offline CBDC model to ensure that transactions can still be conducted without an internet connection, especially crucial during natural disasters or in remote areas with limited connectivity (BILGEN et al., 2024).

In conclusion, while the Sand Dollar has made significant strides in digital currency implementation, addressing the current challenges and focusing on future improvements will be crucial for its success. It is clear that the CBoB is committed to continuously monitoring the performance and user experience of the Sand Dollar. This ongoing evaluation will help identify areas for improvement and adapt the system to better meet the needs of users and the financial ecosystem. The CBoB's commitment to enhancing adoption, expanding use cases, and ensuring system resilience and security positions the Sand Dollar as a pioneering initiative in the digital currency landscape.

5.2 The Digital Yuan (China)

5.2.1 Introduction and Background

The Digital Yuan, also known as the Digital Currency Electronic Payment (DCEP) or e-CNY, is China's central bank digital currency initiative. It is developed and issued by the People's Bank of China (PBOC) with the aim of modernizing the country's payment system, enhancing payment efficiency, and increasing the international use of the Yuan, or Renminbi (RMB).

The concept of the DCEP was first proposed by the PBOC in 2014. The development process accelerated over the following years, with significant progress made by 2020 when pilot programs were launched in several major cities, including Shenzhen, Suzhou, and Chengdu. These pilots involved partnerships with commercial banks, technology companies, and various retail businesses to test the currency's functionality and usability (MU, 2023).

The Chinese CBDC is designed to coexist with the physical Yuan and existing digital payment systems like the widely adopted Alipay and WeChat Pay (QPSOFTWARE, 2021). It aims to provide a secure, efficient, and inclusive payment option that is fully controlled and regulated by the central bank. The initiative is part of a broader strategy to enhance financial inclusion, reduce reliance on cash, and combat illicit financial activities such as money laundering and tax evasion (MU, 2023).

Moreover, the e-CNY has geopolitical implications, as it is seen as a tool to increase the international presence of the Chinese currency and reduce dependence on the US dollar in international trade and finance. This aspect aligns with China's long-term goal of enhancing

its economic sovereignty and influence on the global stage.

The introduction of the Digital Yuan represents a significant milestone in the evolution of China's financial system, showcasing the country's commitment to embracing digital innovation while maintaining stringent regulatory oversight. It represents the inaugural introduction of a sovereign digital currency by a major economy.

5.2.2 Motivations and Objectives

China's motivations for developing and implementing the Digital Yuan are multifaceted, encompassing both domestic and international factors.

Regarding domestic motivations, the Digital Yuan aims to enhance the efficiency of the financial system by providing a more convenient and faster way to conduct transactions compared to traditional cash and banking systems. It supports real-time, 24/7 transactions, reducing settlement times and operational costs for banks and businesses. Moreover, by promoting a digital currency, China seeks to decrease the reliance on physical cash, which is costly to produce, distribute, and maintain. A digital currency can streamline payments and reduce the expenses associated with handling and securing physical money (MU, 2023).

Another strong motivation is the promotion of financial inclusion. The Chinese CBDC can provide banking services to unbanked and underbanked populations, particularly in rural and remote areas where traditional banking infrastructure is limited(CHE, 2021). Mobile wallets and digital transactions can reach these communities more effectively. Besides that, by offering a state-backed digital currency, China aims to lower the barriers for financial access, making it easier for in-

dividuals and small businesses to participate in the economy. This can help in poverty alleviation and economic development. In his regard, the PBOC takes it as its obligation to cater to long-tail users, such as the disabled, the elderly, and non-residents, who could face challenges when trying to access local payment methods (MU, 2023).

The e-CNY allows the PBOC to monitor financial transactions more effectively, helping to combat money laundering, tax evasion, and other illegal activities. The traceability of digital transactions enhances transparency and accountability. Real-time data from digital currency transactions also provides the PBOC with better insights into economic activities, enabling more informed and responsive monetary policy decisions. This can improve the effectiveness of economic interventions. In this way, the DCEP helps strengthen monetary control and oversight of the financial system (MU, 2023).

By pioneering a CBDC, China positions itself as a leader in financial technology. This aligns with the country's broader strategy to become a global innovation hub and enhances its competitiveness in the digital economy(MU, 2023).

Considering international factors, the e-CNY can reduce China's reliance on the US dollar for international trade and finance. By promoting the use of its digital currency in cross-border transactions, China seeks to diversify global trade and mitigate the risks associated with dollar dominance. A reduced dependency on the US dollar enhances China's financial sovereignty and reduces its vulnerability to geopolitical pressures and sanctions imposed by the United States(BANSAL; SINGH, 2022).

The Digital Yuan supports China's goal of internationalizing the RMB. By facilitating easier and more efficient cross-border payments,

the Chinese CBDC can encourage its adoption in global trade and finance, boosting the RMB's global status. The e-CNY, for instance, can play a crucial role in the Belt and Road Initiative (BRI), a China-led economic development project focused on infrastructure investment across Asia, Europe, and Africa (BANSAL; SINGH, 2022). This initiative is expected to channel trillions of dollars into infrastructure-related projects in over seventy countries (MA, 2018). The Digital Yuan, with its benefits of faster and cheaper transactions, offers China the opportunity to reduce costs and increase the ease of conducting cross-border trade and investments along the BRI.

In this way, by offering an alternative to the dollar-based system, China can build stronger economic and political alliances, particularly with countries seeking to reduce their reliance on the US financial system. It also aligns with China's broader strategy of achieving digital sovereignty. By leading in digital currency innovation (MU, 2023), China can set standards and norms in the emerging digital financial landscape, influencing global regulatory frameworks and practices (BANSAL; SINGH, 2022).

Another e-CNY's goal is to facilitate seamless and secure transactions, encouraging domestic consumption and economic activity. This is particularly relevant in the context of China's economic rebalancing strategy, which aims to shift from export-led growth to a more consumption-driven model (ZIPSER, 2023). Moreover, by integrating the Digital Yuan into various sectors, including fintech, e-commerce, and smart cities, China aims to foster innovation ecosystems that drive economic growth and technological advancement (REPUBLIC, 2023).

The implementation of a state-controlled digital currency allows for enhanced cybersecurity measures and protections against cyber threats. This ensures the stability and integrity of the financial system.

The CBDC can facilitate compliance with regulatory requirements by providing transparent and traceable transaction records. This helps in maintaining financial stability and enforcing legal and regulatory standards (MU, 2023).

Therefore, domestically, the DCEP aims to modernize the financial system, enhance financial inclusion, strengthen monetary control, and showcase technological leadership. Internationally, it seeks to reduce dependence on the US dollar, promote the RMB as a global currency, and enhance China's geopolitical influence. The strategic objectives are centered around economic efficiency and growth, regulatory and security goals, and facilitating global trade and investment. Together, these motivations and objectives highlight China's comprehensive approach to leveraging digital currency as a tool for economic and geopolitical advancement.

5.2.3 Implementation and Features

The Digital Yuan is designed as a centralized digital currency issued and regulated by the PBOC. The implementation follows a two-tiered system (1). The PBOC issues the DCEP to commercial banks and other authorized entities, which then distribute it to the public. This structure leverages existing financial institutions to facilitate the distribution and management of the currency (MU, 2023).

The PBOC has been driving the development of the e-CNY since 2014. Between 2014 and 2016, it formed the digital fiat currency research group, initiating research in this field. By 2016, the establishment of the Digital Currency Institute aimed to further develop the proposed designs and fundamental features of the DCEP. At the end of 2019, the implementation of the Digital Yuan pilot program commenced in Shenzhen, Suzhou, Xiong'an and Chengdu. These pi-

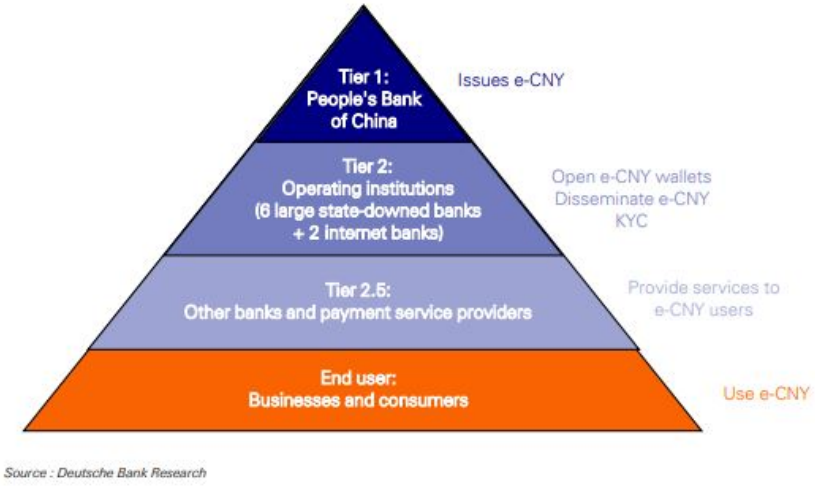

Figure 1 – Source: Deutsche Bank

lots tested the digital currency in real-world scenarios, including retail transactions, government services, and transportation. They involved distributing small amounts of Digital Yuan to selected participants through lotteries (REUTERS, 2021). These participants used the digital currency for everyday purchases, providing feedback on user experience and system performance. Following initial successes, the pilot programs expanded to additional cities and regions. Large-scale events, such as the 2022 Winter Olympics in Beijing, also served as testing grounds for the Digital Yuan's capabilities (MU, 2023).

While not fully blockchain-based, the Digital Yuan incorporates some blockchain and cryptographic technologies to ensure security, traceability, and anti-counterfeiting measures (MU, 2023). Regarding its technology, at the core of the digital yuan's infrastructure is a centralized permissioned Distributed Ledger Technology (DLT), a digital system for recording the transaction of assets in which the transactions and their details are recorded in multiple places at the same time (ROSENBACH, 2020). Unlike public blockchains like Bitcoin, which are decentralized and open to anyone, the DCEP's blockchain is centralized and access is restricted. This means that only autho-

rized participants, such as top-tier intermediaries (TTIs), including major banks and large technology firms like Alibaba (Alipay) and Tencent (WeChat), can validate and record transactions on the blockchain (DIDENKO et al., 2020). This centralized control allows the PBOC to maintain oversight and ensure compliance with national monetary policies.

TTIs are major financial institutions and large technology firms authorized by the PBOC to participate in the DCEP system. These intermediaries play a crucial role in the distribution and management of digital yuan tokens. TTIs receive digital yuan from the PBOC and distribute it to other financial institutions and end users. Examples of TTIs include major commercial banks and leading technology firms. They ensure the secure and efficient operation of the e-CNY by leveraging their existing infrastructure and networks(DIDENKO et al., 2020).

The DCEP operates on a token-based system, where Digital Yuan tokens are issued by the PBOC and distributed to TTIs. In this context, a token represents a digital unit of the yuan, which can be transferred electronically between parties. These tokens function similarly to physical cash in the digital realm, providing a medium for transactions and a store of value. They can be transferred between retail and wholesale accounts, ensuring flexibility and broad usability (DIDENKO et al., 2020). The token-based approach also supports offline transactions, which is crucial for regions with limited internet connectivity.

While initially targeted at TTIs, the DCEP is also accessible to individuals through digital wallets. These wallets can be provided by commercial banks or third-party payment platforms like Alipay and WeChat Pay. Moreover, they can be accessed via mobile apps,

enabling users to store and transact with the digital currency (MU, 2023). This integration ensures that the e-CNY can be used for everyday transactions, from small retail purchases to large-scale business payments, thereby embedding the digital currency into the daily financial activities of the population (DIDENKO et al., 2020).

The Chinese government has established a comprehensive legal and regulatory framework to govern the issuance, distribution, and use of the Digital Yuan. This includes measures to prevent money laundering, fraud, and other illicit activities. The e-CNY employs advanced encryption and authentication mechanisms to ensure the security of transactions and user data. This includes measures to prevent unauthorized access and hacking. Since all transactions made with the Digital Yuan are recorded on a digital ledger, it provides the PBOC with real-time data for monitoring and analysis. This helps in detecting and preventing illicit activities such as money laundering and tax evasion (MU, 2023).

The design of the DCEP includes measures to ensure privacy within the private sector, with users' transaction data kept confidential from other private entities. However, in line with China's regulatory environment, the state retains access to transaction data. This dual approach aims to protect user privacy while enabling the PBOC to monitor financial activities for regulatory and economic stability purposes. The e-CNY incorporates managed anonymity: it operates under the principle of maintaining anonymity for small-value transactions while ensuring traceability for high-value transactions. This approach aims to balance the protection of user privacy with the need to prevent criminal activities (MU, 2023).

Furthermore, the Digital Yuan enables seamless and instant transactions, both online and offline. Users can make payments using their

digital wallets without the need for an internet connection, thanks to NFC (Near Field Communication) technology (QPSOFTWARE, 2021). Moreover, the digital currency is designed to be interoperable with existing payment systems, allowing users to switch between Digital Yuan and traditional payment methods easily(MU, 2023).

Beyond that, the DCEP supports programmability through smart contracts, which can automate certain financial processes and transactions. This feature enables more sophisticated financial services and applications. Users can set conditions for payments, such as releasing funds only when specific criteria are met (MU, 2023). This can be useful for various use cases, including escrow services and automated billing.

The e-CNY aims to provide universal access to financial services, including for those without traditional bank accounts. This is achieved through easy-to-use mobile apps and minimal requirements for opening digital wallets(MU, 2023).

Therefore, the implementation and features of the Digital Yuan reflect China's ambitious efforts to modernize its financial system and assert its leadership in the digital economy. The phased implementation process, involving pilot programs, collaboration with financial institutions, and a robust regulatory framework, has laid a solid foundation for the Digital Yuan's adoption. The currency's features—convenience, security, traceability, programmability, and inclusivity—highlight its potential to transform both domestic and international financial landscapes.

5.2.4 Benefits and Challenges

The Digital Yuan provides a means of financial access to unbanked and underbanked populations. With a mobile phone and internet access - or even without internet access-, individuals can participate in the digital economy. Besides that, the e-CNY reduces reliance on physical cash, lowering transaction costs and making financial services more affordable and accessible to a broader population (MU, 2023).

The DCEP bolsters China's initiatives to internationalize the RMB, significantly amplifying its utilization in global trade and finance. This can diminish dependence on the US dollar, thereby reinforcing China's economic sovereignty. Moreover, the CBDC can be used in BRI projects, simplifying cross-border transactions and fostering economic ties with participating countries. China also positions itself as a leader in the development of digital currency standards and protocols by pioneering a state-backed digital currency, potentially shaping global financial norms and practices. Such initiative enhances China's influence and strengthens its position as a global economic leader (BANSAL; SINGH, 2022).

Having a CBDC reduces the costs associated with printing, distributing, and managing physical cash, leading to significant savings for the government and financial institutions. The e-CNY also provides the PBOC with real-time data on economic activity, enabling more effective and timely monetary policy decisions. It contributes to economic stability and growth. Besides that, the DCEP stimulates the fintech sector by encouraging the development of new financial products and services; hence, fostering innovation and competition, driving overall economic advancement (MU, 2023).

The Digital Yuan's traceability and authentication features reduce

the risk of fraud, counterfeiting, and money laundering. The digital ledger records all transactions, providing transparency and accountability. This enhancement of the financial system's integrity helps deter illicit activities and improves regulatory compliance (MU, 2023).

The centralized nature of the Digital Yuan raises concerns about government surveillance and data privacy. Users may be apprehensive about the extent to which their financial activities are monitored and recorded (XIA et al., 2023). In this way, ensuring robust privacy protections while maintaining the security and traceability of transactions is a complex challenge. Finding the right balance is crucial to gaining public trust and acceptance (MU, 2023).

The implementation of a nationwide digital currency necessitates a highly scalable and reliable technical infrastructure, capable of processing high transaction volumes without experiencing outages or delays. Given the digital nature of the currency, it is inherently susceptible to cyberattacks and hacking attempts, thereby necessitating rigorous cybersecurity measures to protect against these threats. Furthermore, the integration of the Digital Yuan with existing financial systems, payment platforms, and banking infrastructure requires meticulous planning and execution to prevent disruptions and ensure seamless functionality (XIA, 2021).

Encouraging widespread adoption of the Digital Yuan necessitates effectively communicating its benefits to the public while addressing any concerns or misconceptions. High levels of user adoption are critical for the currency's success. To facilitate a smooth transition, it is imperative to provide comprehensive education and raise awareness about the DCEP, emphasizing its advantages and the safety measures in place. This effort should include targeted campaigns and the development of user-friendly resources to ensure broad and informed

participation (XIA et al., 2023).

The introduction of the e-CNY has the potential to significantly disrupt traditional banking models, impacting the role and profitability of commercial banks (BITTER, 2023). To remain competitive, these institutions may need to adapt their business strategies and operational frameworks. Establishing a comprehensive regulatory framework to govern the use of the Digital Yuan, addressing cross-border implications, and ensuring compliance with international standards represents a formidable regulatory challenge (MU, 2023). Additionally, the Chinese CBDC could alter market dynamics, affecting competition among financial institutions and payment providers (BITTER, 2023). Understanding and managing these impacts is crucial to maintaining a stable and robust financial ecosystem.

The achievement of global acceptance and interoperability of the Digital Yuan with other digital currencies and traditional currencies is a complex task (MU, 2023). It requires international collaboration and agreements. The rise of the DCEP could intensify geopolitical tensions, particularly with countries that perceive it as a challenge to the dominance of their own currencies. Navigating these tensions diplomatically is essential.

The Digital Yuan offers significant benefits, including financial inclusion, enhanced geopolitical influence, economic efficiency, and improved security and transparency. However, it also faces substantial challenges related to privacy, technical implementation, public adoption, regulatory implications, and international relations. Successfully addressing these challenges will be crucial for the long-term success and global acceptance of the e-CNY. As China continues to develop and refine its digital currency, its impact on the global financial landscape will be closely watched and analyzed.

5.2.5 Current Status and Future Outlook

Since its initial pilot programs in 2019, the Digital Yuan has undergone extensive testing across various cities and regions in China, including Shenzhen, Suzhou, Chengdu, and Xiong'an New Area. These pilot initiatives encompassed diverse sectors such as retail, transportation, and government services, facilitating comprehensive evaluations of its operational efficacy and societal impact.

By mid-2023, the Digital Yuan had garnered significant traction, with the opening of 120 million digital wallets and a pronounced surge in transactional throughput. Specifically, the aggregate transaction volume had soared to 950 million yuan, culminating in a cumulative value of 1.8 trillion yuan (equivalent to US$249.9 billion). This substantial growth marked a notable escalation from the previous August, where transactions amounted to 100 billion yuan (approximately US$13.9 billion), underscoring the expanding user base and escalating transaction frequency observed within a relatively short timeframe. Moreover, in 2022, 5.6 million merchants registered were reported using the e-CNY (NULIMAIMAITI, 2023).

China is already on track to increase yuan circulation via the BRI. In 2023, trade volume with BRI member nations totaled 19.47 trillion yuan (about US$2.74 trillion), this accounted for 46.6% of China's total trade, an increase of 1.2 percentage points from 2022 (PRC, 2024). China is the largest trade partner to around twenty-five countries along the BRI and has established currency swap agreements with more than twenty BRI nations. To further support the initiative, China is promoting the use of the yuan for cross-border trade. Using its digital currency for cross-border transactions would allow China to bypass the existing US-centric financial system, shielding its

BRI activities from US sanctions and bolstering China's geopolitical and trade position(BANSAL; SINGH, 2022).

Concerning the political significance of the cross-border payment system, Bulla (2023) points out that, in the context of the Ukraine War, upon the United States and its allies' decision to curb Russia's advances through economic and financial sanctions, global concern escalated. This shift highlighted how money has become a tool of warfare susceptible to military conflict interference. Consequently, many nations began seeking reliable alternatives, turning to China's international payment system (CIPS) as a substitute for the dominant global payment system under US control, known as Swift. CIPS conducts financial settlements in yuan or e-CNY, potentially boosting trade and investment with China by streamlining exports and capital transfers.

Smart contracts are already being implemented in China, representing a significant advancement in promoting transparency, efficiency, and automation in transactions (BHARDWAJ, 2023). Integrated into the e-CNY platform, these smart contracts enable secure and verifiable agreements between parties without intermediaries, thereby simplifying transaction processes (MU, 2023). This technological integration not only enhances transparency by enabling real-time tracking and auditing of transactions but also improves operational efficiency by automating contract execution and settlement procedures. Furthermore, they contribute to reducing administrative costs and mitigating risks associated with human error, thereby enhancing the reliability and integrity of digital transactions within the rapidly growing ecosystem of the Digital Yuan. This implementation underscores the transformative potential of blockchain technology in reshaping financial infrastructures and emphasizes its implications for future research on digital currencies and financial technologies.

The Chinese government plans to gradually expand the use of the Digital Yuan to cover the entire country. This phased rollout aims to ensure stability and address any technical or operational issues that arise during the process. Besides that, China aims to contribute to the development of global standards for digital currencies, collaborating with international organizations to shape the future of digital finance.

The DCEP is progressing steadily, with extensive pilot programs, growing adoption, and a solid technological and regulatory foundation. Its future plans include a national rollout, internationalization efforts, technological innovations, public engagement, and evolving policies. As China continues to advance the Digital Yuan, its impact on the global financial system and digital currency landscape will be significant, setting a precedent for other nations exploring similar initiatives.

5.3 The Digital Real (Brazil)

5.3.1 Introduction and Background

After the enactment of a 2013 law which empowered the Central Bank of Brazil (BCB) to regulate retail payments based on principles of efficiency, security, interoperability, and financial inclusion, the acceleration of digitalizing retail payments in Brazil gained momentum. Throughout history, private Payment Service Providers (PSPs) have been fundamental in promoting the financial inclusion of households and small entrepreneurs. Pix was then further developed considering these aspects.

In 2018, the BCB began the works to launch an instant payment scheme developed, managed, operated and owned by the central bank. In this manner, on November 2020, Pix was launched, with the goals

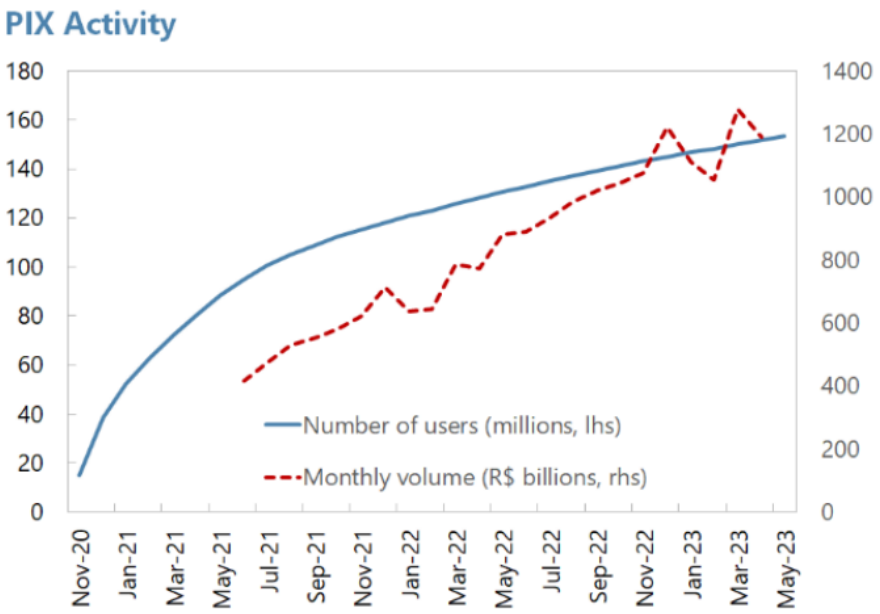

Figure 2 – Source: BCB

of enhancing efficiency and competition. In Pix, the BCB is the system operator and the rulebook owner. In this regard, as the system operator, the BCB fully developed the infrastructure and manages the platform as a public good, and, as the owner of the rulebook, the BCB sets, in accordance with its legal mandate for retail payments, the rules and technical specifications, such as the Application Programming Interfaces (APIs). According to Duarte et al. (2022), this approach fostered a "standardised, competitive, inclusive, safe and open environment, improving the overall payment experience for end-users" (p.5).

Since its introduction, Pix has experienced notable expansion (2). According to the Brazilian Government (2023), as of the end of October 2023, which marks 3 years since its launch, 164 million users had engaged in Pix transactions, and it was responsible for including 71.5 million users in the financial system. Furthermore, as of mid June 2024, Pix has reached a monthly averaged volume around R$ 2 trillion (Us$ 363.61 billion) (BARCELLOS, 2024).

Notably, Pix transactions have not only surpassed various previously prevalent instruments such as pre-paid cards but have also equaled the usage of credit and debit cards. Pix has, in part, taken the place of other digital payment methods like bank transfers. However, it's essential to highlight that the overall volume of digital transactions has significantly increased.

Duarte et al. (2022) state that "retail CBDCs and fast payment systems can be seen as two instances in a broader continuum of payment infrastructures" (p.8). In this way, both employ digital identification, public key cryptography and APIs to ensure the confidentiality of payments, and they also enable private sector providers to deliver cost-effective services through various interfaces.

Infante et al. (2022) highlights that, notwithstanding the resemblances between a retail CBDC and a typical payment platform like Pix, a CBDC would represent a claim on a central bank rather than on private intermediaries, facilitating more direct settlement. Moreover, CBDC systems might also enable novel functionalities, such as programmability (smart contracts), which are presently unavailable in bank transfers or retail fast payments.

Therefore, the Brazilian Central Bank Digital Currency, known as Drex, would be activated when it is essential to condition a financial transaction. Funds would only be debited from the account once the contracting individual receives the product or service as per the agreement. This digital currency could be utilized for significant transactions, such as real estate sales, or for engaging in lending services(BCB, 2023a).

The Drex initiative marks a significant step in the country's efforts to modernize its financial infrastructure and adapt to the rapidly

evolving global financial landscape. The Digital Real represents a digital form of the Brazilian real (BRL), designed to coexist with physical cash and traditional banking systems.

The concept of the Digital Real was introduced in response to the increasing digitization of economies worldwide and the growing interest in CBDCs by central banks globally. As part of Brazil's broader financial inclusion strategy, the Digital Real aims to provide secure, efficient, and accessible digital payment solutions to all Brazilians, especially those who are unbanked or underbanked.

The Central Bank of Brazil has emphasized that the Digital Real is not intended to replace physical currency but to complement it, offering an additional, modern payment method (MALAR, 2023). This initiative is part of a larger trend observed in Latin America, where several countries are exploring digital currencies to enhance financial stability and economic resilience (LATIN. . . , 2023).

The journey towards the Digital Real began with extensive research and consultation with various stakeholders, including financial institutions, technology providers, and regulatory bodies. The Central Bank of Brazil conducted several studies to understand the potential impacts of a CBDC on the economy, the financial system, and society as a whole.

Discussions and initiatives regarding the potential issuance of a digital currency by the BCB began in August 2020. This led to the establishment of guidelines for the Digital Real in May 2021. Since then, the BCB has closely monitored the increasing use of financial transactions within DLT ecosystems in the Brazilian economy. Collaboration with the private sector and academia enabled a thorough analysis of potential issuance models for the Digital Real. Consequently,

in February 2023, the BCB revised the Digital Real guidelines and commenced testing a platform for Digital Real operations, the "Piloto RD", in March 2023, in accordance with the new guidelines (BCB, 2023b).

Therefore, the Digital Real is a forward-looking initiative by the BCB aimed at leveraging digital technology to enhance the nation's financial infrastructure. It reflects Brazil's commitment to innovation and inclusivity in its financial system, ensuring that all citizens can benefit from the advancements in digital finance.

5.3.2 Motivations and Objectives

When launching Drex, the BCB's primary objectives are to reduce banking operation costs, such as those associated with the issuance of paper currency, and to increase the number of people participating in the financial market. According to the Central Bank (GUIA..., 2023), the focus is on "consumers connected to the digital world." This initiative aligns with broader trends in digital finance aimed at increasing financial inclusion and streamlining monetary transactions. By reducing the reliance on physical cash, Drex is expected to enhance the efficiency of the financial system and make financial services more accessible to a wider population, particularly those who are already integrated into the digital ecosystem.

A survey conducted by the BCB reveals a significant increase in financial inclusion, with 82% of the population holding a bank account in 2022, compared to 57% in 2017 (AGUIAR, 2024). Drex has the potential to further accelerate this trend by integrating the remaining 18% of the population into the financial system.

The Digital Real aims to bridge this gap by providing a widely

accessible digital payment solution that does not rely on traditional banking infrastructure. By leveraging mobile technology and digital wallets, the Digital Real can reach individuals who are excluded from the formal financial system (BCB, 2023b). This initiative supports the BCB's broader goal of ensuring that all Brazilians have access to financial services, enabling them to save, borrow, and conduct transactions more effectively.

Another significant motivation is to improve the efficiency of Brazil's payment system. The existing payment infrastructure, while robust, can be slow and costly, especially for small transactions. Traditional payment methods often involve multiple intermediaries, leading to delays and higher transaction costs. The Digital Real is designed to streamline the payment process by reducing the need for intermediaries and enabling instant, low-cost transactions(DREX. . . , 2024). This increased efficiency can benefit consumers and businesses alike by lowering transaction fees, speeding up settlement times, and reducing the administrative burden associated with cash handling(BCB, 2023c). For businesses, especially small and medium-sized enterprises (SMEs), the Digital Real offers a more efficient way to manage payments, improving cash flow and operational efficiency(BCB, 2024).

Embracing technological innovation is a key objective for the BCB. Drex represents an opportunity to modernize the country's financial infrastructure and harness the benefits of emerging technologies such as blockchain and distributed ledger technology. These technologies can enhance the security, transparency, and efficiency of financial transactions, paving the way for further innovation in the financial sector (BCB, 2023d).

On the global stage, the adoption of the Digital Real positions Brazil as an economy that is adapting to the digital transformation

in finance. As more countries explore and implement CBDCs, having a digital currency can enhance Brazil's international competitiveness, facilitating cross-border trade and financial transactions. The Digital Real can also strengthen Brazil's role in the global financial system by enabling interoperability with other digital currencies and fostering international collaboration (BCB, 2024).

By promoting the use of Drex, the BCB aims to reduce the size of the informal economy, which remains significant in Brazil. With a digital currency, all transactions are registered and traceable, making it harder for illegal activities and tax evasion to occur due to more transparency. This shift towards a more formalized economy can improve tax collection and support public finances (GONçALVES, 2023).

The motivations behind the Digital Real are enhancing financial inclusion, improving payment system efficiency, fostering technological innovation, boosting international competitiveness, reducing the informal economy and supporting transparency on financial transactions. These objectives reflect Brazil's commitment to creating a more inclusive, efficient, and resilient financial system through the adoption of a CBDC.

5.3.3 Implementation and Features

The implementation of the Digital Real is a complex, multi-phase process that involves careful planning, extensive testing, and collaboration with various stakeholders. The BCB has adopted a strategic approach to ensure the successful rollout of the Digital Real, focusing on interoperability, security, privacy, and user accessibility.

Drex pilot phase (Piloto RD) was initiated in March 2023. This phase involves collaboration with various financial institutions and

technology providers to test the system's functionalities, security, and efficiency. The pilot aims to refine the technology, address potential challenges, and gather valuable feedback before a broader rollout.

The pilot project was conducted in controlled environments with selected commercial banks, fintech companies, and other stakeholders (BCB, 2023e). The project focuses on various aspects, including transaction speed, security, interoperability, and user experience. The feedback from this pilot is being used to refine the design and implementation strategy.

This pilot project for Drex includes three main categories of participants: i) Authorized Institutions, which have direct access to accounts and digital liabilities of the Central Bank, enabling them to facilitate transactions and manage digital currency; ii) Simulated End Users, the final users who will conduct retail transactions using Drex in its digital ("tokenized") form, representing Real balances held in financial institutions (demand deposits) or payment institutions (electronic money); and iii) National Treasury Secretariat (STN), responsible for issuing Federal Public Securities and settling transactions involving these securities through Delivery versus Payment (DvP) at the final customer level (BCB, 2023e). This diverse group of participants ensures comprehensive testing and validation of Drex's functionalities and security in a controlled environment.

One of the strategic decisions in implementing the Digital Real is its integration with Pix. Since it has already achieved widespread adoption, Pix provides a robust infrastructure for digital transactions. Hence, the BCB aims to ensure that the Digital Real is seamlessly integrated into existing payment ecosystems, making it easy for users to adopt and use the new currency. This integration promises to enhance the financial ecosystem by connecting Pix to a broader range of finan-

cial services such as credit, investments, and insurance (RONCHI, 2024).

Moreover, the BCB is investing in the necessary technological infrastructure to support the Digital Real. This includes developing secure and scalable systems for the issuance, distribution, and transaction of the digital currency. Advanced security measures are being implemented to protect Drex from cyber threats and ensure the integrity of the system. A comprehensive regulatory framework is being established to govern the use of the Digital Real. This framework addresses key issues such as data privacy, anti-money laundering (AML), counter-terrorist financing (CTF), and consumer protection. The regulatory framework aims to create a secure and transparent environment for the Digital Real, fostering trust and confidence among users (BCB, 2023d).

Drex will operate on a two-tiered system. In the first tier, the BCB (2023d) issues the digital currency to commercial banks. In the second tier, these banks distribute the Digital Real to the public and businesses. This system leverages the existing banking infrastructure, ensuring efficient distribution and integration with current financial services.

Beyond that, Drex supports smart contract functionality, enabling programmable transactions. This feature allows for automatic execution of transactions based on predefined conditions, enhancing the flexibility and efficiency of financial operations. Programmable money can be used for various applications, including automated payments, conditional disbursements, and more complex financial products (BCB, 2024).

Moreover, Drex aims to serve as an infrastructure that, for the first

time, integrates both money and financial assets in a single platform (GUIA..., 2023). This includes assets such as stocks, debentures, government bonds, and even property certificates for real estate and automobiles. By consolidating these various financial instruments, the BCB seeks to create, with Drex, a comprehensive digital financial ecosystem.

The anticipated effects of this integration include the development of better and more profitable financial products for all participants in the financial chain, from issuers to investors. This integration is expected to enhance the efficiency and availability of investment opportunities, eliminating the constraints imposed by traditional banking hours. Additionally, it opens up the potential for the creation of new financial instruments.

Lastly, the Digital Real provides the BCB with real-time data on economic transactions. This capability enhances the central bank's ability to monitor economic activity, implement monetary policy, and respond to economic changes swiftly and accurately.

Thus, the implementation strategy and features of the Digital Real reflect Brazil's commitment to creating a secure, efficient, and inclusive digital currency. By leveraging existing infrastructure like PIX, engaging stakeholders, and incorporating advanced technological features, the BCB aims to ensure the successful adoption and operation of the Digital Real.

5.3.4 Benefits and Challenges

One of the most significant benefits of the Digital Real is its potential to improve financial inclusion. This inclusion can empower individuals to participate more fully in the economy, access credit,

save money, and make transactions more conveniently.

Furthermore, digital currencies like the Digital Real offer enhanced security features compared to physical cash and traditional payment methods. Advanced encryption and cybersecurity measures can protect users from fraud and theft. Additionally, the use of blockchain and DLT can provide a tamper-proof record of transactions, reducing the risk of counterfeiting and financial crimes (BCB, 2023e).

Another benefit is that Drex can help reduce the size of Brazil's informal economy by increasing the transparency and traceability of transactions (GONçALVES, 2023). With real-time monitoring, the BCB can better detect and prevent illicit activities, such as money laundering and tax evasion.

The adoption of the Brazilian CBDC fosters technological innovation within Brazil's financial sector. The digital currency can pave the way for new financial products and services, such as programmable money, smart contracts, and automated compliance solutions. This innovation can drive economic growth and position Brazil as a leader in digital finance.

Moreover, the integration of Drex with Pix represents a significant advancement in the digitalization of Brazil's financial system. The Digital Real will link Pix to diverse financial services, such as access to credit and to investments, creating a comprehensive fintech ecosystem. Beyond that, the combination of Drex and Pix will provide a richer and more diverse experiences for business and end-users, catering to broader financial needs through a unified interface. Additionally, developers can explore new functionalities and integrate complex services thanks to Drex's interoperability (RONCHI, 2024). Thus, this integration is poised to strengthen Pix's role as a central

financial tool, expanding transaction possibilities and services within the financial ecosystem.

Therefore, among the primary advantages of Drex are its operational efficiency, enabling rapid financial transactions, and its potential for seamless global utilization without significant barriers. Moreover, Drex is underpinned by a robust security infrastructure designed to deter fraud, enhancing the overall safety of digital transactions. Additionally, it offers a substantial reduction in the costs associated with financial movements, making it a highly cost-effective option for both consumers and businesses.

However, there are some anticipated challenges to consider regarding the implementation of Drex.

Firstly, effective integration of various market participants, including commercial banks, regulatory authorities, and marketplaces, is essential. This integration must ensure seamless verification of identities, transactions, and assets.

Concerning digital inclusion, ensuring that all individuals, regardless of their location or socioeconomic status, have access to Drex is crucial. Digital literacy and access to necessary technologies remain significant hurdles. Besides that, users need to understand how to use Drex, including performing transactions and managing their digital currency. The BCB has a crucial role in educating the public about these new financial tools.

With respect to data security and privacy, while blockchain technology is inherently secure, external factors can still pose risks to user data. Ensuring the protection of user data from threats is paramount.

Lastly, encouraging broad acceptance of Drex as a payment method,

particularly among smaller or traditional businesses, is essential for its success. Overcoming resistance to new technologies and ensuring all merchants can handle digital payments is a significant challenge

Therefore, the successful implementation of Drex depends on addressing these challenges while maximizing its potential benefits. The BCB must balance transparency with privacy, ensuring that the new digital currency fosters innovation, inclusivity and security within the financial system.

5.3.5 Current Status and Future Outlook

The pilot project for the "tokenization" of the Brazilian Real, spearheaded by the BCB, has experienced delays. Initially set to conclude privacy tests this year, the pilot has been extended into a second phase starting in July 2024 and continuing until mid-2025 (BOMFIM, 2024). This phase will focus on implementing additional functionalities such as smart contracts, allowing the private institutions that are participating in the pilot project to create innovative services and business models within the Drex platform. The BCB has also announced an open call for new participants interested in the project.

The delays were primarily due to technological solutions for transaction privacy not meeting the necessary legal requirements. Privacy solutions from Zether, Starlight, and Rayls(formerly Parchain) have been tested for various transaction flows, including wholesale digital real transfers and tokenized real digital transactions (BOMFIM, 2024).

In the pilot phase of Drex project, various privacy solutions were evaluated to ensure the secure and private handling of transactions within the digital real ecosystem. The Zether protocol was tested for digital real transfer flows and the purchase and sale of public securities.

In contrast, Starlight was assessed solely for the purchase and sale of public securities using the digital real. Rayls, distinctively, is the only protocol undergoing implementation and testing across all four transaction flows by the project participants (BOMFIM, 2024).

Furthermore, the BCB plans to scrutinize Microsoft's ZKP Nova, a novel privacy solution not initially included in the project scope. ZKP Nova, recognized for its potential to enhance transaction privacy and scalability through high-speed recursive proofs, may be tested by consortia should the BCB's evaluation find it viable (BOMFIM, 2024). This addition underscores the commitment to integrating advanced privacy technologies to meet stringent legal and security requirements for digital transactions.

Despite the challenges, significant progress has been made. The test of many privacy solutions and transaction flows highlights the complexities involved in ensuring privacy, scalability, and transaction speed within a blockchain environment.

Concerning the future outlook, the second phase of the Drex project aims to further develop and mature the platform, ensuring it meets privacy requirements before including the general public in pilot tests. Key areas of focus will include the integration of new use cases, such as vehicle registration, Certificates of Deposit (CDBs), and real estate transactions.

While privacy remains a critical challenge, solutions are being explored to balance confidentiality with the scalability and speed of transactions. The successful implementation of Drex could revolutionize the financial landscape in Brazil, providing a secure, efficient, and innovative digital currency system.

The BCB's commitment to continuous testing and improvement,

coupled with the participation of diverse stakeholders, positions Drex for a promising future. However, the timeline for its full-scale public launch has been adjusted, with a phased rollout expected between late 2024 and early 2025. As the project progresses, the BCB's focus will remain on addressing technological, legal, and operational challenges to ensure the successful deployment of Drex.

5.4 The US Digital Dollar (USA)

5.4.1 Introduction and Background

The concept of the US Digital Dollar has been a topic of significant interest and debate within financial and governmental circles in the United States. The initiative aims to modernize the monetary system and address the growing demands of a digital economy. The initiative aims to modernize the financial system, enhance payment efficiency, and ensure the US dollar's continued relevance in the evolving digital economy.

In 2020, the discussion around a digital dollar intensified when the COVID-19 pandemic underscored the need for efficient and secure digital payment systems. The CARES Act, passed by Congress in March 2020, included a proposal for a digital dollar to facilitate direct payments to Americans. Although the proposal was not immediately implemented, it catalyzed further exploration and research into the potential benefits of a CBDC (SHELTON, 2020).

The primary objectives of the US Digital Dollar include improving the efficiency, security, and inclusivity of the payment system. By introducing a state-backed digital currency, the FED aims to provide a reliable and accessible means of payment that complements exist-

ing financial infrastructure. As other countries, notably China with its Digital Yuan, advance their own CBDC projects, the US aims to maintain its competitive edge in the global financial system.

The FED has engaged with a broad range of stakeholders, including financial institutions, technology companies, regulatory bodies, and the public. This collaborative approach aims to gather diverse perspectives and ensure that the US Digital Dollar addresses the needs and concerns of all relevant parties. Public consultations and discussions with industry experts have been a key part of the development process, contributing to the design and implementation strategy of the digital currency.

Beyond that, developing a comprehensive regulatory framework is crucial for the successful implementation of the US Digital Dollar. The FED, in coordination with other regulatory agencies, is working on establishing guidelines that address issues such as data privacy, cybersecurity, AML and consumer protection. In this way, the regulatory framework aims to create a secure and transparent environment for the digital currency, fostering trust and confidence among users and stakeholders.

The implementation of the US Digital Dollar requires robust technological infrastructure. The Federal Reserve is exploring various technological options, including DLT and other secure, scalable systems to support the issuance, distribution, and transaction of the digital currency. Thereby, ensuring the technological infrastructure can handle high transaction volumes while maintaining security and reliability is a key focus of the initiative.

The introduction of the US Digital Dollar represents a proactive approach to modernizing the US financial system and maintaining

the global prominence of the US dollar. However, the timeline for full implementation remains uncertain, with ongoing discussions about the best approach to ensure security, privacy, and efficiency.

5.4.2 Motivations and Objectives

One of the primary motivations behind the US Digital Dollar is to ensure the continued global dominance of the US dollar. As other countries develop their own CBDCs, the US seeks to maintain its influence in the international monetary system by providing a digital version of its currency that is widely accepted and trusted globally. The US Digital Dollar aims to counteract the potential threats posed by other CBDCs and private digital currencies, which could undermine the dollar's status as the world's primary reserve currency. The following motivations were taken from the consultations with financial institutions, technology firms, regulatory bodies, and the general public.

The US dollar is the world's most widely used currency for payments and investments, and it serves as the global reserve currency. This status provides significant benefits to the United States, such as lower transaction and borrowing costs for households, businesses, and the government, as well as influence over global monetary standards (FED, 2022). A US CBDC could help maintain this dominant role by ensuring that the dollar remains competitive as other countries develop and potentially deploy their own CBDCs. Without a US CBDC, the dollar's influence in cross-border payments might be diminished if other nations' CBDCs offer more efficient or secure payment options (FED, 2023).

With major economic powers like China advancing their own digital currency projects, the US is motivated to ensure that the dollar

does not lose its competitive edge in international finance. The implementation of the US Digital Dollar could prevent other currencies from gaining a technological advantage that might erode the dollar's usage in international trade and finance (FED, 2023).

Another motivation is the improvement of the payment system efficiency. A CBDC could modernize the payment system, increasing competition and potentially lowering costs. This is particularly relevant for merchants and smaller payment providers who could benefit from reduced fees and improved service efficiency. Moreover, the programmability of CBDCs could support new payment services, such as automated payments based on specific conditions (smart contracts), thus fostering innovation in financial services and business models (FED, 2023).

Furthermore, the US Digital Dollar could improve cross-border payment processes by increasing efficiency and reducing costs. This is crucial as international transactions remain a significant aspect of global trade. Improved interoperability with other CBDCs could facilitate smoother cross-border financial operations, benefiting global commerce and reinforcing the dollar's role in international markets. In this regard, FED (2023) points out that a wholesale CBDC could be a better alternative, since it could have fewer risks than a retail CBDC, such as bank disintermediation.

The development of a US CBDC also aims to enhance the stability and security of the financial system. By providing a new, secure form of central bank money, a CBDC could reduce reliance on potentially less stable digital currencies, such as cryptocurrencies and privately issued stablecoins, which might pose systemic risks. A Digital Dollar could also provide a safe, reliable form of digital money for the public if the use of physical cash declines, ensuring that the central bank's

monetary policies continue to be effective in a digital economy (FED, 2023).

A US CBDC has the potential to improve financial inclusion by providing low-cost, accessible financial services to underserved populations. This could be particularly impactful in reducing the number of unbanked and underbanked individuals by offering a secure, government-backed digital payment option (FED, 2023).

Therefore, the motivations behind the US Digital Dollar focus on maintaining and enhancing the global dominance of the US dollar, improving the efficiency and security of the financial system, supporting international trade, and promoting financial inclusion. These objectives reflect the US's strategic interests in adapting to the evolving digital economy while preserving its financial and economic leadership on the global stage.

5.4.3 Implementation and Features

The development of the US Digital Dollar is currently in the research and development phase. The FED has been conducting extensive research to understand the potential benefits and risks associated with a CBDC. This phase involves collaboration with various stakeholders, including other government agencies, financial institutions, academic researchers, and technology experts. The goal is to gather comprehensive insights and develop a well-informed strategy for the potential implementation of a digital currency.

The research and development phase of the US CBDC has been characterized by extensive experimentation and analysis conducted by the FED. This phase has included technological experimentation, economic and policy research, and stakeholder engagement.

The Federal Reserve Board's Technology Lab has been involved in building a hypothetical CBDC that leverages existing technologies and systems. This includes exploring centralized CBDC designs that could be integrated with the current financial infrastructure. Beyond that, experiments with DLT have also been conducted, focusing on how DLT could support interbank settlements. This research seeks to assess the feasibility and advantages of using blockchain and other DLTs in enhancing the efficiency and security of wholesale payments (FED, 2022).

Additionally, the Federal Reserve Bank of Boston, in collaboration with the Massachusetts Institute of Technology's Digital Currency Initiative, has been developing alternative platforms utilizing newer technologies, such as blockchain. This project, known as Project Hamilton, aims to understand the potential and limitations of different technological solutions for a CBDC. It was lauched at the beginning of 2020 and concluded by the of the year (LINDSAY, 2022).

In this manner, the project provided critical insights into how money might function better in the future, contributing valuable data for the development of secure, scalable, and flexible CBDC solutions. It developed OpenCBDC, an open-source transaction processor designed to handle high-performance and resilient CBDC transactions, achieving a throughput of 1.84 million transactions per second with settlement times under one second. This processor includes features like programmability and audit capabilities, offering a comprehensive framework to evaluate design choices for potential CBDCs.

Moreover, the FED is also engaged in extensive economic and policy research. This research covers a range of topics including financial inclusion, financial stability, privacy considerations, and the implications of CBDCs on monetary policy. The goal is to ensure that the Digital

Dollar would support the broader objectives of economic stability and inclusion. Specific projects include examining how a CBDC could be designed to enhance financial inclusion, especially for cash-based and vulnerable populations. This involves analyzing the potential benefits and challenges of providing digital payment options to these groups (FED, 2022).

The FED has been actively engaging with stakeholders from the private sector, academia, and international organizations (such as six other central banks). This engagement is aimed at gathering a wide range of perspectives on the design, implementation, and potential impacts of a CBDC. The Innovation Office Hours hosted by Federal Reserve banks serve as a platform for these dialogues, helping to shape the research and development process based on diverse inputs (FED, 2022).

While the exact design of the US Digital Dollar has not yet been finalized, insights from FED documents and consultations highlight several critical considerations necessary to ensure the effectiveness, security, and compatibility of a US CBDC with existing financial systems. These considerations include ease of use and acceptance, security and privacy, operational resilience, and legal and regulatory frameworks.

A primary design goal is to ensure the CBDC is user-friendly and widely accepted at points of sale. This includes designing the CBDC to be easily transferable across various payment platforms. Mobile wallet technology, which can facilitate quick and convenient transactions, has been identified as a potential tool for increasing adoption and lowering implementation costs. Furthermore, commenters from the consultations have emphasized the need for common standards in data and messaging, identity and authentication, security, and legal

and regulatory frameworks to ensure interoperability and wide acceptance. Adopting international standards can help avoid the high costs associated with unique national standards and promote global compatibility(FED, 2023).

Moreover, security is a paramount concern in the design of the CBDC, especially given the rapid evolution of technology. For instance, the potential threat posed by quantum computing to current cryptographic methods is being considered, as some academics and technology companies have pointed out (FED, 2023), prompting the exploration of advanced cryptographic solutions to safeguard the CBDC.

In such manner, balancing privacy with regulatory requirements is another key challenge. The CBDC must provide sufficient privacy to users while ensuring it does not facilitate illicit activities. This balance involves designing privacy features that protect consumer data without compromising the ability to monitor and prevent financial crimes. The design must also account for operational and cyber resilience. This involves implementing robust security measures to protect against cyber threats and ensuring the CBDC system can withstand and recover from operational disruptions. This resilience is critical to maintaining public trust and the stability of the financial system (FED, 2022).

Regarding legal and regulatory framework, legal tender status is another important consideration. While some stakeholders support designating the CBDC as legal tender, similar to physical cash, others highlight practical implications, such as mandatory acceptance at all points of sale, which need careful consideration (FED, 2023). The role and regulatory structure of intermediaries that will handle the CBDC transactions is also being explored. Decisions regarding whether the CBDC should pay interest, have offline capabilities, and the limits on

the amount held by single end-users are part of the ongoing design considerations (FED, 2022).

Thus, the research and development phase of the US Digital Dollar is a complex and multi-faceted process involving extensive experimentation, stakeholder engagement, and careful consideration of economic, technological, and policy factors. The goal is to develop a CBDC that not only meets the needs of the US economy but also upholds the principles of security, privacy, and financial stability.

5.4.4 Benefits and Challenges

A US Digital Dollar could significantly enhance the efficiency and speed of payment systems. Digital transactions can be processed faster than traditional methods, reducing settlement times and increasing the overall speed of financial transactions. Moreover, the adoption of a digital dollar can lower transaction costs by eliminating intermediaries and reducing the need for physical cash handling. This can benefit both consumers and businesses by making transactions more economical (FED, 2022).

Digital currency can make financial services more accessible to rural and remote areas, enhancing overall financial inclusion and economic participation. A US CBDC has the potential to bring financial services to the unbanked and underbanked populations. By providing a digital means of transaction, individuals without access to traditional banking services can participate in the digital economy using mobile devices. However, FED (2023) underscores that the issuance of a US Digital Dollar has the potential to exacerbate the "digital divide," particularly affecting individuals who lack reliable internet and mobile access, such as the elderly and those from low-income backgrounds.

Concerning economic stability, a digital dollar could provide the FED with new tools for monetary policy implementation. It could, for instance, enable more precise control of money supply and improve the transmission of monetary policy actions directly to consumers. During economic crises, digital dollars could be distributed quickly and directly to individuals, providing timely and efficient economic relief (FED, 2022).

Beyond that, a well-designed CBDC would be able to enhance transparency and traceability in financial transactions, making it easier to combat money laundering, tax evasion, and other illicit activities. This is possible through the implementation of robust tracking and reporting mechanisms (FED, 2022).

Furthermore, the introduction of a US CBDC can help maintain and even enhance the global dominance of the US dollar. As other nations develop their own CBDCs, having a Digital Dollar ensures that the US remains competitive in the evolving global financial landscape. FED (2022) mentions that a US Digital Dollar could streamline cross-border transactions, reducing costs and enhancing the efficiency of international payments. This can reinforce the dollar's role as the primary global reserve currency.

On the other hand, FED (2022) also recognizes that developing a comprehensive regulatory framework that governs the issuance, distribution, and usage of the Digital Dollar is a significant challenge. This includes ensuring compliance with existing financial regulations and adapting to new regulatory needs specific to digital currencies. Defining the roles and responsibilities of intermediaries, such as banks and payment service providers, is crucial. Ensuring that these entities comply with regulatory standards while facilitating CBDC transactions is a complex task.

One of the major challenges is balancing user privacy with the need for security and regulatory compliance. While users expect their financial data to be protected, regulators require sufficient transparency to prevent illicit activities. Designing a CBDC that meets both needs is intricate (FED, 2022). Ensuring robust data protection mechanisms to safeguard users' personal and financial information against cyber threats and misuse is essential. This involves implementing advanced encryption and secure data storage solutions.

Moreover, the establishment of the requisite infrastructure to support a US Digital Dollar entails substantial technological advancements. This encompasses the development of a secure and scalable platform capable of managing a high volume of transactions efficiently. Furthermore, safeguarding the US CBDC system from cyberattacks and ensuring its operational resilience are of paramount importance. This necessitates continuous monitoring and the regular updating of security protocols to defend against the ever-evolving landscape of cyber threats.

The introduction of a Digital Dollar could also disrupt the traditional banking sector. Banks might face reduced deposits as consumers and businesses hold digital dollars directly, which could impact their ability to lend and provide other financial services. Beyond that, while a US CBDC provides new tools for monetary policy, it also presents challenges. The central bank needs to carefully manage the digital dollar supply to avoid unintended economic consequences, such as inflation or deflation (FED, 2023).

Lastly, ensuring public trust in the US Digital Dollar is crucial for its successful implementation. This requires transparent communication regarding its benefits, security measures, and intended usage. Overcoming skepticism and securing public confidence present signif-

icant challenges. Encouraging widespread adoption and usage of the US CBDC necessitates addressing potential user concerns related to privacy, security, and ease of use. The development of a user-friendly and widely accepted digital currency is essential to its success (FED, 2023).

Therefore, while the US Digital Dollar presents numerous benefits, including enhanced payment systems, financial inclusion, and maintaining global currency dominance, it also faces significant challenges related to regulatory compliance, privacy, technological infrastructure, and public acceptance. Addressing these challenges is essential for the successful implementation and widespread adoption of the digital dollar.

5.4.5 Current Status and Future Outlook

The FED has been actively engaged in researching and exploring the potential for a US Digital Dollar. Despite the significant interest and ongoing discussions, the Federal Reserve Chair Jerome Powell has indicated that the institution is "not remotely close" to launching a CBDC (SCHROEDER, 2024), emphasizing the need for thorough research and consideration of potential risks and benefits. Some of the key concerns include the potential impacts on financial stability, privacy, and the traditional banking system. This highlights the cautious and methodical approach being taken, prioritizing thorough research and stakeholder consultation over rapid implementation.

Beyond that, the FED has initiated public consultations to gather feedback from a wide array of stakeholders, including financial institutions, technology companies, consumer advocacy groups, and the general public. These consultations aim to understand the potential benefits, risks, and societal impacts of a digital dollar, ensuring that

any future implementation aligns with public interest and addresses key concerns.

The introduction of a US Digital Dollar necessitates comprehensive legislative and regulatory frameworks to address issues such as privacy, security, and financial stability. Current discussions involve evaluating existing laws and potentially drafting new regulations to govern the use and oversight of a digital dollar. This process involves coordination with various government agencies, including the Treasury Department and Congress.

The Federal Reserve is expected to continue its rigorous research and testing efforts in the coming years. Further experimentation and development of prototypes will be crucial in refining the design and functionality of the digital currency. If the FED ever decides to issue a US CBDC, given its complexity and potential impact, a phased and gradual implementation strategy is likely. Initial phases may involve limited pilots and controlled rollouts to specific user groups or sectors, allowing the FED to monitor and evaluate the system's performance, security, and user experience. Feedback from these early stages will inform subsequent phases and broader deployment plans.

One of the primary challenges in implementing a Digital Dollar is ensuring robust privacy and security measures. The FED will need to balance transparency with the need to protect user data and transaction privacy. Advancements in cryptographic techniques, such as zero-knowledge proofs (ZKPs), will play a pivotal role in achieving this balance. ZPKs, for instance, are cryptographic protocols that allow one party (the prover) to prove to another party (the verifier) that a statement is true, without revealing any additional information beyond the validity of the statement itself (D, 2024). In other words, ZKPs enable proving knowledge of a piece of information without dis-

closing the actual information or compromising privacy. In this way, ongoing research and collaboration with cybersecurity experts will be essential to mitigate risks and enhance the digital dollar's resilience against cyber threats.

A critical aspect of the US Digital Dollar's future outlook involves its integration with existing financial systems and infrastructure. This includes interoperability with current payment networks, banking systems, and other digital currencies. The FED will need to work closely with financial institutions, payment service providers, and technology firms to ensure seamless integration and interoperability, fostering a cohesive digital financial ecosystem.

Developing a robust policy and governance framework will be essential for the successful implementation and operation of a digital dollar. This framework will need to address issues related to monetary policy, financial stability, and regulatory oversight. Clear guidelines on the issuance, distribution, and use of the Digital Dollar will help build trust and confidence among users and stakeholders. The Federal Reserve will also need to establish mechanisms for monitoring and managing the digital currency's impact on the broader economy.

The current status of the US Digital Dollar reflects a deliberate and comprehensive approach to exploring the feasibility and implications of a CBDC. Through extensive research, collaborative initiatives, and public consultations, the FED is laying the groundwork for a potential future Digital Dollar. As research and testing progress, the focus will remain on addressing key challenges related to privacy, security, regulatory compliance, financial stability and technological integration. While a fully operational US CBDC may still be several years away, the ongoing efforts will provide valuable insights and pave the way for a secure, efficient, and inclusive digital currency in the United States.

6 Comparative Analysis

6.1 Comparative Framework

To conduct a thorough comparative analysis of the Sand Dollar, Digital Yuan, Digital Real and US Digital Dollar, it is necessary to consider: i) the motivations, the driving factors behind the launch of each CBDC; ii) their implementation strategies, analysing the approach and phases involved in the development and rollout of the CBDC; iii) the design features, the key technical and functional characteristics of each CBDC; iv) their benefits, the advantages observed or even anticipated from the implementation of the CBDCs; and v) the challenges, the difficulties and risks encountered or expected during the implementation and operation of the CBDCs.

6.2 Comparison Across Case Studies

Concerning the first aspect, the primary motivation for the Bahamas' Sand Dollar was to improve financial inclusion in the archipelago, where many residents lacked access to banking services due to geographical constraints. Additionally, it aimed to modernize the payment system and reduce transaction costs.

China's motivation for the Digital Yuan is multifaceted, including enhancing the efficiency of the payment system, reducing reliance on the US dollar, and increasing control over the financial system. It also aims to support the internationalization of the yuan.

The Central Bank of Brazil's motivation for the Digital Real is centered on enhancing financial inclusion, improving the efficiency of

the payment system, and fostering innovation in financial services. In this way, Brazil aims to create a comprehensive financial ecosystem, bringing a significant number of Brazilians into the financial market.

The US Digital Dollar is motivated by the need to maintain the US dollar's global dominance, improve payment system efficiency, and provide a secure and resilient financial infrastructure. Moreover, the US CBDC would serve as an alternative to private sector digital currencies.

In regard to the implementation strategy, the Bahamas adopted a phased implementation strategy, starting with pilot projects in selected regions, the Exuma and Abaco islands. This allowed for testing and refining the digital currency before nationwide rollout, ensuring a smoother transition.

China has adopted a gradual and controlled rollout strategy, with extensive pilot programs in various cities. The PBOC collaborated with state-owned banks and technology firms to implement the e-CNY and to test it in various scenarios, ensuring robust testing and refinement before broader adoption.

Drex is being developed with a focus on collaboration with the private sector and academia. The BCB conducted extensive research and consultation throughout the pilot phase, which helps to assess the digital currency's performance and integration with existing financial systems.

On the other hand, the US Federal Reserve is still in the research and exploration phase, engaging with stakeholders from various sectors to understand the implications and design requirements. The implementation strategy emphasizes careful consideration of regulatory, technological, and operational aspects.

With respect to design features, the Sand Dollar is designed to be a direct liability of the central bank, with a focus on interoperability with existing payment systems. It is accessible through digital wallets and aims to provide a secure and efficient means of payment.

The e-CNY features dual offline payments, interoperability with existing payment systems, and programmability through smart contracts. It is designed to support managed anonymity.

Drex emphasizes interoperability with the existing Pix payment system, incorporation of smart contracts capabilities for programmable transactions, and a two-tier distribution model where the central bank issues the digital currency to commercial banks for further distribution.

The design features of the US Digital Dollar are still under exploration. However, key considerations include privacy, scalability, security, interoperability with existing financial systems and compliance with regulatory standards.

Regarding the benefits, the implementation of the Sand Dollar provided enhanced financial inclusion, especially in remote areas, reduced transaction costs, improved efficiency in payments and reduced reliance on cash. The Bahamian CBDC also supports economic resilience in times of crisis, such as during natural disasters.

The Digital Yuan provides increased efficiency in the payment system and reduced reliance on cash. The DCEP also provides greater control over the financial system, support for cross-border trade and promotion of the yuan's international use, strengthening China's geopolitical influence.

With the Digital Real, the potential benefits are improved finan-

cial inclusion, reduced transaction costs, enhanced payment system efficiency and widening of the Brazilians' financial ecosystem. Moreover, the implementation of Drex intends to improve the traceability of transactions, aiding in fraud prevention.

A US Digital Dollar would contribute for the maintenance of the US dollar's global dominance. It would also increase efficiency and speed of payments, provide a secure alternative to private digital currencies, and could provide innovation and enhancement of the financial structure.

As for the challenges, the CBoB still has technological challenges to overcome, concerning to ensure a secure and reliable infrastructure. Beyond that, limited digital literacy and internet access in remote areas pose adoption barriers.

The PBOC has to manage: privacy concerns due to government surveillance capabilities; potential impacts on the banking sector, considering its size; the coexistence with existing payment systems; and to ensure interoperability with international systems.

The BCB has to overcome technological and operational challenges, ensuring data privacy and regulatory compliance when integrating Drex with existing financial regulations. The central bank also has to ensure widespread adoption and usability across diverse populations.

The US has significant regulatory and privacy concerns, especially regarding data security and surveillance. Developing a infrastructure for the US Digital Dollar would also require a robust and scalable system, which could impact the existing financial system and monetary policies. These potential impacts need careful consideration.

6.3 Key Insights and Lessons Learned

Comparing the Sand Dollar, Digital Yuan, Digital Real, and US Digital Dollar offers several key insights and lessons that can inform the development and implementation of CBDCs. These insights span motivations, strategies, design features, and the broader implications of introducing CBDCs into diverse economic and financial systems.

One of the primary insights from the comparative analysis is that the motivations behind the implementation of CBDCs are diverse and reflect the unique economic, political, and social contexts of each country.

A primary motivation for CBDC in the Bahamas is to enhance financial inclusion. This country faces significant portions of their populations lacking access to traditional banking services. By offering a digital currency, the CBoB aims to provide a secure, accessible, and efficient means of financial transactions, thereby integrating the unbanked and underbanked into the formal financial system.

For China, motivations extend to enhancing the efficiency of its payment systems, providing the government with better tools for monetary control and reducing reliance on the US dollar in international trade. Similarly, the US Digital Dollar would aim to maintain the US dollar's global dominance and improve the efficiency and security of the domestic payment system. These motivations reflect broader economic and geopolitical objectives, highlighting the strategic importance of CBDCs.

Furthermore, a common strategy observed across the case studies is the use of phased implementation and pilot programs to test and refine the CBDCs before full-scale deployment. By initially launching

in limited regions or with specific user groups, central banks can test the technology, gather user feedback, and make necessary adjustments before a full-scale rollout.

For instance, China's extensive pilots in cities like Shenzhen and Suzhou provided valuable insights into the Digital Yuan's operational effectiveness and user adoption. The Bahamas adopted a phased rollout, starting with pilots in the Exuma and Abaco islands, allowing the CBoB to address challenges and refine the Sand Dollar's features based on real-world feedback. Brazil's approach with Drex includes sector-specific pilots to test the currency's integration with retail payments, government disbursements, and other use cases, ensuring comprehensive evaluation across different sectors. This approach helps mitigate risks and ensures a smoother transition to digital currencies.

It is important to highlight that collaboration with financial institutions, technology providers, and other stakeholders is crucial. The Central Bank of the Bahamas, People's Bank of China, Central Bank of Brazil, and the US Federal Reserve all engage extensively with relevant stakeholders to refine their strategies, address concerns, and build a supportive ecosystem for their CBDCs.

Moreover, the design and technological choices of each CBDC are tailored to meet their specific goals, emphasizing security, efficiency, and interoperability. Thus, ensuring interoperability with existing financial systems is a key design feature across all CBDCs. The Sand Dollar integrates with digital wallets, the e-CNY works alongside existing payment platforms, the Digital Real aligns with Brazil's Pix system, and the US Digital Dollar aims to be compatible with current financial infrastructures. This interoperability is essential for seamless user experience and widespread adoption.

While the potential benefits of CBDCs are substantial, significant challenges must be addressed to realize these benefits fully. Much as CBDCs like the Sand Dollar, the DCEP and Drex have demonstrated potential in enhancing financial inclusion and improving payment efficiency, adherence to the digital currencies remains a big challenge.

Beyond that, addressing cybersecurity risks and privacy concerns is paramount. Each CBDC must balance robust security measures with user privacy to build trust and ensure the integrity of the financial system. The Digital Yuan, for instance, raises concerns about government surveillance and data privacy, highlighting the need for robust data protection measures (managed anonymity).

Lastly, the implementation of CBDCs also involves navigating complex regulatory landscapes and operational risks. Therefore, ensuring regulatory compliance is not trivial, requiring careful attention.

In this way, the development of CBDCs spurs innovation in financial technologies and promotes competition in the payment services sector. Countries that lead in CBDC implementation may set standards and best practices, influencing global financial trends and technological advancements.

7 Conclusion

The comparative analysis of the Sand Dollar, Digital Yuan, Digital Real, and US Digital Dollar reveals that Central Bank Digital Currencies (CBDCs) present unique opportunities and challenges shaped by each country's specific context. The motivations driving CBDC development vary significantly: enhancing financial inclusion in the Bahamas, improving payment efficiency and reducing reliance on the US dollar in China, maintaining global financial dominance in the US, and integrating with existing digital payment systems in Brazil.

Phased implementation and pilot programs emerge as essential strategies for successful CBDC deployment. These approaches allow central banks to test technological solutions, gather user feedback, and make necessary adjustments before full-scale implementation. The importance of stakeholder collaboration, including financial institutions, technology providers, and the public, is underscored across all case studies. Effective engagement ensures the development of supportive ecosystems and addresses potential concerns early in the process.

The design and technological choices of each CBDC are tailored to meet their specific goals, emphasizing security, efficiency, and interoperability. Integrating CBDCs with existing financial systems is crucial for achieving widespread adoption and ensuring a seamless user experience. The Sand Dollar's integration with digital wallets, the Digital Yuan's compatibility with existing payment platforms, the Digital Real's alignment with Pix, and the US Digital Dollar's planned interoperability with current financial infrastructures highlight the necessity of this approach.

Despite the potential benefits, significant challenges must be ad-

dressed to realize the full potential of CBDCs. Cybersecurity risks and privacy concerns are paramount, requiring a delicate balance between robust security measures and user privacy. Additionally, navigating complex regulatory landscapes and operational risks is essential for ensuring compliance and maintaining the integrity of the financial system.

Key insights from the comparative analysis emphasize the need for tailored approaches that consider local economic conditions, technological infrastructure, and user needs. Early and continuous stakeholder engagement fosters trust and acceptance, while robust testing and iterative development allow central banks to refine their CBDC offerings based on real-world feedback.

In conclusion, the introduction of CBDCs has significant implications for financial innovation, competition in payment services and global economic dynamics. Countries that lead in CBDC implementation may set standards and best practices, influencing global financial trends and technological advancements. The lessons learned from the Sand Dollar, Digital Yuan, Digital Real, and US Digital Dollar highlight the complexities and opportunities in developing and deploying CBDCs, offering valuable guidance for other nations considering similar initiatives.

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