



FINTECH

NOTES

Behind the Scenes of Central Bank Digital Currency

Emerging Trends, Insights, and Policy Lessons

Gabriel Soderberg

In collaboration with Marianne Bechara, Wouter Bossu, Natasha Che,
Sonja Davidovic, John Kiff, Inutu Lukonga, Tommaso Mancini-Griffoli, Tao Sun,
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1. Introduction

Central banks are increasingly pondering whether to issue their own digital currencies to the general public, so-called retail central bank digital currency (CBDC).¹ The majority of IMF member countries are actively evaluating CBDCs, with only a few having issued CBDCs or undertaken extensive pilots or tests.²

This paper shines the spotlight on the handful of countries at the frontier in the hope of identifying and sharing insights, lessons, and open questions for the benefit of the many countries following in their footsteps. Clearly, what can be gleaned from these experiences does not necessarily apply elsewhere. The sample of countries remains small and country circumstances differ widely. However, the insights in this paper may inspire further investigation and allow countries to gain time by building on the experience of others. Importantly, the purpose of this paper is not to evaluate the courses taken by different jurisdictions, but to study and discuss their key experiences and lessons.

The paper studies six advanced CBDC projects, drawing on collaboration and exchanges with the respective central banks to get insights beyond what has previously been published. Unless a specific published source is cited, all information stems from interviews and workshops with members of CBDC project teams in each jurisdiction.³

The chosen CBDC projects fulfill at least one of the following criteria:

- a. *A CBDC is already issued.* Selected project: Central Bank of The Bahamas (CBOB).
- b. *A pilot CBDC has been or is being tested involving actual households and firms.* Selected projects: People's Bank of China (PBOC), Eastern Caribbean Central Bank (ECCB),⁴ and Banco Central de Uruguay (BCDU).
- c. *A CBDC project has been brought onto the country's political agenda and is being analyzed by government or parliamentary bodies outside of the central bank.* Selected project: Sveriges Riksbank.
- d. *The central bank has carried out a CBDC project and decided against issuing a CBDC for the time being.* Selected project: Bank of Canada (BOC).

Importantly, these countries have different national contexts and their CBDC projects are at different stages of development (see Box 1 for a quick overview). Thus, the information that central banks can provide differs. Whether or when these projects, except for that of the Bahamas, eventually evolve into an officially launched CBDC offered to the general public remains to be seen.

The structure of this paper is based on the primary considerations for a CBDC project and is summarized graphically in Figure 1. Importantly, all these considerations should be viewed as being carried out with sound processes for risk identification and mitigation.⁵

This paper first explores the policy goals of the different jurisdictions. It then reviews the operational models for CBDC, that is, who issues and distributes CBDC and the respective roles of the central bank and the private sector. The paper then turns to the design features of CBDC, which range from ways to

¹ CBDC is digital money issued by a central bank and is conceivable in both retail and wholesale form. Retail CBDC, or sometimes general purpose CBDC, refers to CBDC that can be held and used by individuals, whereas wholesale CBDCs are available only to a selected set of financial institutions. For more on these different types, see BIS (2018).

² For a recent survey of CBDC projects around the world, see Boar and Wehrli (2021). For online resources that are updated continuously, see Atlantic Council (2021) and Kiff (2021).

³ These central banks have also been given the opportunity to read and comment on the text before publication. Any errors remain the responsibility of the author.

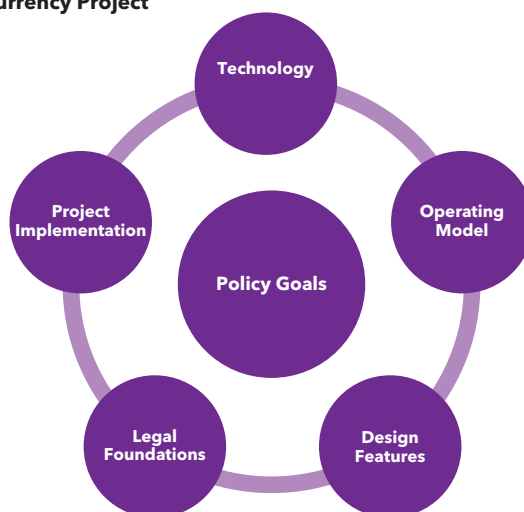
⁴ The ECCB is the monetary authority in the Eastern Caribbean Currency Union (ECCU), which is a monetary union consisting of Anguilla, Antigua and Barbuda, Dominica, Grenada, Montserrat, St. Kitts and Nevis, Saint Lucia, and St. Vincent and the Grenadines.

⁵ For a discussion of different risks that a central bank needs to consider in a CBDC project, see Kiff and others (2020) and Khan and Malaika (2021).

BOX 1. Current Status of CBDC Projects

- *CBOB, Sand Dollar*: The Sand Dollar was officially launched in October 2020. In late 2021, there were around 20,000 active Sand Dollar wallets in a population of about 400,000, and functions are continuously being developed.
- *BOC*: The BOC has not found a pressing case for a digital currency given the present state of the Canadian payments system. However, it continues to build the technical capacity to issue a CBDC, and monitor developments that could increase its urgency.
- *PBOC, e-CNY*: No formal decision has been taken to launch the e-CNY. The PBOC runs a pilot in parallel in different regions. By October 2021, there were over 123 million e-CNY wallets registered with individuals and about 9.2 million wallets held by firms—a rapid increase from approximately six million active e-CNY wallets in April 2021. In a population of nearly one and a half billion, the share of e-CNY users is now approaching 10 percent.
- *ECCB, DCash*: No decision has been made to formally issue DCash. In March 2021, the ECCB launched a pilot program to successively extend DCash throughout the countries of the Eastern Caribbean Currency Union (ECCU) and run the program for 12 months. Given its rapid adoption, ECCB is now considering transitioning to an official CBDC launch.
- *Sveriges Riksbank, e-krona*: No decision has been made to issue the e-krona. The Riksbank has developed a proof of concept and is exploring technological and policy angles of CBDC. A government inquiry is investigating the role of the state in the digital payments system, including the potential role of a CBDC.
- *BCDU, e-peso*: After ending a pilot in 2018, the BCDU has changed leadership and has opted to not pursue a second pilot due to other priorities and a lack of resources. Potentially, a second pilot will be launched in the future.

Figure 1. The Main Choices and Considerations for a Central Bank Digital Currency Project



Source: IMF staff.

mitigate risks to uses in cross-border payments. Next, the paper considers options available to jurisdictions on specific technologies and moves to the legal foundations of CBDC. The last section examines the process of exploring and testing CBDC, such as organizational choices and staffing. It also includes insights identified as particularly important by the jurisdictions themselves on the way forward.

2. Policy Goals of CBDC Projects

Policy goals for CBDC naturally guide the ensuing exploration and work. These goals also help establish guidelines to make design and technology choices.

The goals differ across jurisdictions, reflecting factors like the characteristics of the payment systems and various perceived domestic challenges. Mandates may also be a consideration. Central bank laws often establish the function of promoting efficient, safe, and secure payment systems, or set efficient and effective monetary policy, both of which may be relevant to CBDC.

However, the themes of modernizing and/or future-proofing countries' payment systems ran across the various goals stated by the central banks reviewed in this paper. Modernizing is about improving the payment system through increasing digitalization. And future-proofing refers to updating a payment system that is already extensively digitalized to counter potential future risks associated with continuous innovation.

This section discusses the different policy goals that each jurisdiction identified as crucial. Other goals may also exist and be important, but of lesser priority.

A. Financial Inclusion

Financial inclusion is a common policy goal for CBDC projects. Financial inclusion entails access to appropriate and affordable financial services and is associated with poverty reduction worldwide.⁶ But despite significant progress, large parts of the world's population remain financially underserved. Increasing financial inclusion has many challenges, including access to digital technology. CBDC could potentially facilitate financial inclusion by increasing access to digital payments and thus serving as a gateway to wider access to financial services.

Most of the six jurisdictions in this survey identify financial inclusion as a top policy goal. In the Bahamas, pockets of the population are excluded from financial services because they live in regions where it is not profitable for commercial actors to operate. Approximately 20 percent of the adult population is estimated to have no bank account.⁷ Geography exacerbates the problem since the Bahamas consists of many islands, which are costly to serve.

Likewise, the ECCU consists of island nations where it has been difficult for financial institutions to develop economies of scale and find profitable channels of expansion. Foreign banks have increasingly withdrawn from the region, citing low profitability. The result is lower financial inclusion.

Uruguay has also seen a sluggish development of financial services for a significant part of the population. The government has actively sought to stimulate its development, including by making a digital option mandatory for essential payments.⁸

While China has made rapid progress in financial inclusion and digitalization, the population in remote regions remain underbanked and underserved by mobile payment operators. The PBOC has sought to promote digital payments and financial inclusion for two decades, but estimates that around 10 percent of the Chinese population still lack access to basic financial services.⁹ Meanwhile, some financial institutions that focus on local business have difficulties in digitalizing due to their technological capabilities. PBOC now sees extending financial inclusion to this part of the population as a key policy goal for the e-CNY.

⁶ For an overview of financial inclusion, see World Bank (2021), Ozili (2020), and Dev (2006).

⁷ IMF (2019), p.13.

⁸ The Financial Inclusion Law was enacted in 2014.

⁹ For more on financial inclusion in China, see World Bank and PBOC (2018).

B. Access to Payments

Helping facilitate payments among the population is an important objective for central banks in most countries.¹⁰ Access to payments is associated with, but not identical to, financial inclusion. Even countries with high levels of financial inclusion, such as Sweden, can still face access to payments challenges. Some central banks are concerned that private payment service providers might not find extending services to all parts of the population sufficiently profitable, and that a declining use of cash will exacerbate the problem. Some jurisdictions are therefore exploring if a CBDC could help achieve or safeguard universal access to payments.

Access to payments may encounter multiple hurdles, including shortage of cash, firms' refusal to accept cash, and lack of or recurring disturbances of digital infrastructure. In the Bahamas, for example, the island geography creates difficulties in both distributing cash and extending digital infrastructure. This is why the CBOB has listed access to payments—regardless of age, social status, or location—as one of its most important goals.¹¹

In countries in which cash usage is dwindling, access to payment is also a key concern. Some segments of the population still rely on, or prefer, making cash payments, but may run into limitations. One of the Riksbank's top priority goals for the e-krona project is to ensure broad access to payments in the years ahead.¹² In particular, the Riksbank has identified the elderly and groups with certain disabilities as potentially adversely affected in a cashless society. While the Riksbank is committed to ensuring that cash will still be available and possible to use in the future,¹³ it is also exploring how CBDC could facilitate the creation of digital payments especially suitable for these groups as a complement to cash.

The BOC also emphasizes access to payments as a key policy goal despite near-universal financial inclusion. If cash availability falls beneath a certain level, some groups might experience difficulties in making payments. These groups include individuals in remote areas where private firms find it unprofitable to operate, with low income, and with different forms of impairments.¹⁴ A potential CBDC could hence be designed with universal access in mind.¹⁵

C. Making Payments More Efficient

In countries where cash and check use is high, operational costs are elevated. And in some countries, existing digital payments are also relatively expensive. CBDC is therefore a potential policy tool to offer digital forms of payments that are cheaper to operate. The non-profit nature of central banks means that they could potentially offer low-cost payments as a public good, potentially subject to the need to eventually recover costs.

The Bahamas and the ECCU are high-cost jurisdictions for both physical and existing digital payments. In the Bahamas, an important additional consideration has been the high cost for government agencies to make cash-based payments to citizens who lack bank accounts. There are plans to integrate government agencies in the Sand Dollar network to support digital government payments to individuals to lower this cost.¹⁶

¹⁰ For a discussion on the general role of central banks in payments, see BIS (2003).

¹¹ CBOB (2019).

¹² Sveriges Riksbank (2018).

¹³ The Riksbank is also analyzing legal forms to strengthen cash. See Sveriges Riksbank (2021a).

¹⁴ BOC (2020), p.7.

¹⁵ Miedema and others (2020).

¹⁶ CBOB (2019).

While the Chinese payments market in urban areas is already highly digitalized, the PBOC has expressed a desire to improve its payment services. It sees this as part of an ongoing international effort by central banks to improve their services to the public, comparable to the roll-out of instant payments platforms.

D. Ensuring Resilience of Payments

Ensuring the ability to pay and extending government transfers to individuals under severe circumstances is important for all jurisdictions, but the urgency of this policy goal is especially high in disaster-prone nations. For the Bahamas and the ECCU, resilience is thus considered a key policy goal. Both consist of islands in a region where natural disasters are frequent. Destruction of physical, financial infrastructure and impediments to shipping cash are immediate concerns. In the Bahamas, a hurricane in 2019 precipitated the start of the Sand Dollar pilot in the same year to facilitate assistance payments to and within afflicted areas.

Likewise, the ECCB accelerated the expansion of its DCash pilot to areas affected by a volcano eruption in St. Vincent and the Grenadines in 2021.

Countries with a highly digitalized payment sector are concerned about disruption to digital services and concentration risks where there are only a few large operators. In China, for example, the mobile payment market is dominated by two firms, AliPay and TenPay/WeChat Pay. The PBOC has expressed concern that the failure of such firms could have serious consequences to the Chinese payments system. One of the crucial policy goals expressed by the PBOC is for the e-CNY to function as a backup to existing digital payment solutions.

Similarly, the Riksbank has identified single points of failure among a few dominant actors as a potential risk that would be exacerbated in a society in which cash is no longer available as a backup or “redundancy” system. The resilience of payments has also become an important part of the country’s ongoing modernization of civil defense.¹⁷ While the Riksbank advocates the continued existence of cash, the e-krona could potentially serve as an additional backup to existing forms of digital payments.

The BOC has also noted that cash can function as a backup when digital payments are unfunctional, and that falling cash usage might thus mean impaired payments resilience. CBDC could therefore potentially play a role as an additional backup.¹⁸

E. Reducing Illicit Use of Money

Some features of cash, including anonymity and the lack of an audit trail,¹⁹ make it attractive for illicit transactions (for example, tax evasion, money laundering, and terrorist financing). CBDC could potentially reduce this problem.

At this point, however, only the Bahamas has reduction of the illicit use of money as a top policy objective for its CBDC. The background to this objective is an ongoing campaign to strengthen the Anti-Money Laundering / Combating Financing of Terrorism (AML/CTF). The Bahamas was put on the Financial Action Task Force (FATF) *grey list* in 2018 due to strategic deficiencies in its AML/CFT framework, which resulted in increased monitoring. The Bahamian authorities subsequently implemented an action plan aimed at addressing the identified deficiencies, and as a result, the Bahamas was de-listed in December 2020.²⁰

¹⁷ Utredningen om civilt försvar (2021).

¹⁸ BOC (2020), Miedema and others (2020).

¹⁹ FATF (2015).

²⁰ FATF (2020).

F. Monetary Sovereignty

While currency substitution has long been a risk facing countries, it is possible that new forms of digital currency might have a competitive advantage relative to older forms of currencies. If a sufficiently large portion of a country's population adopts a foreign digital currency or a global stablecoin, the ability of the country to carry out several crucial central bank functions might be impaired, such as monetary policy and lender of last resort.²¹

The BOC has stated that serious consideration of a CBDC might be triggered if monetary sovereignty were to become an issue—say if Canadians began adopting a non-Canadian digital currency or stablecoin.²² Likewise, the PBOC has said that one motivation for investigating CBDC was to secure monetary sovereignty in a digital future.²³

G. Competition

CBDC could potentially increase competition in a country's payments sector in two ways: directly, by competing with existing forms of payments; and indirectly, should the CBDC be designed as a platform open to private payment service providers (see the following section, Operating Model). The latter would ensure low barriers of entry for new firms seeking to offer new payment services.

The Riksbank, in particular, sees competition as a potentially important contribution by the e-krona. The payments market, according to Riksbank analysis, displays clear network effects that tend to favor the concentration of a few large actors. This may lead to high fees or stagnating innovation in the future. The e-krona could be a way to ensure more competition and enhance market efficiency.²⁴

The BOC has also said that the high concentration of service providers in the Canadian financial system may be contributing to the high costs of payments. If cash were to decline significantly, competition in the Canadian payments market would decline even more. This is among the reasons why the BOC is monitoring cash usage and building capacity to launch a potential CBDC.

H. Summary of Policy Goals

The different policy goals of the jurisdictions in this survey are summarized in Table 1.

Table 1. Jurisdictions' Stated Policy Goals of Central Bank Digital Currency

Country	Financial Inclusion	Access	Efficiency	Illicit Use of Money	Resilience	Sovereignty	Competition
Bahamas	✓	✓	✓	✓	✓		
Canada		✓			✓	✓	✓
China	✓	✓	✓		✓	✓	✓
ECCU	✓		✓		✓		
Sweden		✓	✓		✓		✓
Uruguay	✓		✓				

Sources: Central banks.

Note: ECCU = Eastern Caribbean Currency Union.

²¹ For example, IMF (2020a) and BIS and others (2021).

²² BOC (2020).

²³ For example, Mu (2021).

²⁴ Sveriges Riksbank (2017, 2018); Soderberg (2019).

3. Operating Model

A crucial choice is how CBDC will be issued and circulated, and what the role of the central bank and the private sector will be. We refer to this overarching structure as the operating model.²⁵ Different names and classifications are used in other literature and there is no established standard for the typology of different operating models.²⁶

In the first model, which we call *unilateral CBDC*, the central bank carries out all functions in the payments system, from issuing the CBDC to distributing it, and interacting with end-users.

The second model entails issuance by the central bank, but includes a role for private sector firms to interact with the end-user. We refer to these agents as *intermediaries* and the model in which they operate *intermediated CBDC*. The intermediary role can be filled by financial firms, but also other types of companies such as payment service providers and mobile phone operators. Most would likely be privately-owned and for-profit firms, but state-owned intermediaries and cooperatives may also be involved.²⁷ This second model would require the central bank to regulate and/or oversee other actors, which adds an extra layer of legal and operational complexity.²⁸

In the third model, digital currency is issued not by the central bank but by private firms that back the issuance by holding central bank liabilities. Hence, the third model is not a CBDC, but rather a stablecoin, or a special type of e-money, as it is not issued by a central bank and may be referred to as *synthetic CBDC* or *sCBDC*. But as it is backed one-to-one by central bank-issued assets, it may be considered by some central banks as an alternative to CBDC, and is therefore included in this paper.

These conceptual models should not be seen as mutually exclusive. Some central banks are considering the intermediated model as their main operating model, but also offering basic payment services through a unilateral model to ensure universal access and resilience. Likewise, an sCBDC is not necessarily a replacement for CBDC and could, for instance, be issued by private firms alongside, or even backed by, CBDC.²⁹

These three conceptual models are depicted in Figure 2.

These conceptual operating models are useful starting points for discussions on CBDC design. So far, there is a convergence on the intermediated model. No central bank in this survey has explored the unilateral or synthetic CBDC models and the rest of this section will focus on the intermediated model.³⁰

²⁵ This follows the concept used in Kiff and others (2020).

²⁶ For example, see Armelius and others (2020), BOE (2020), and Auer and Böhme (2020).

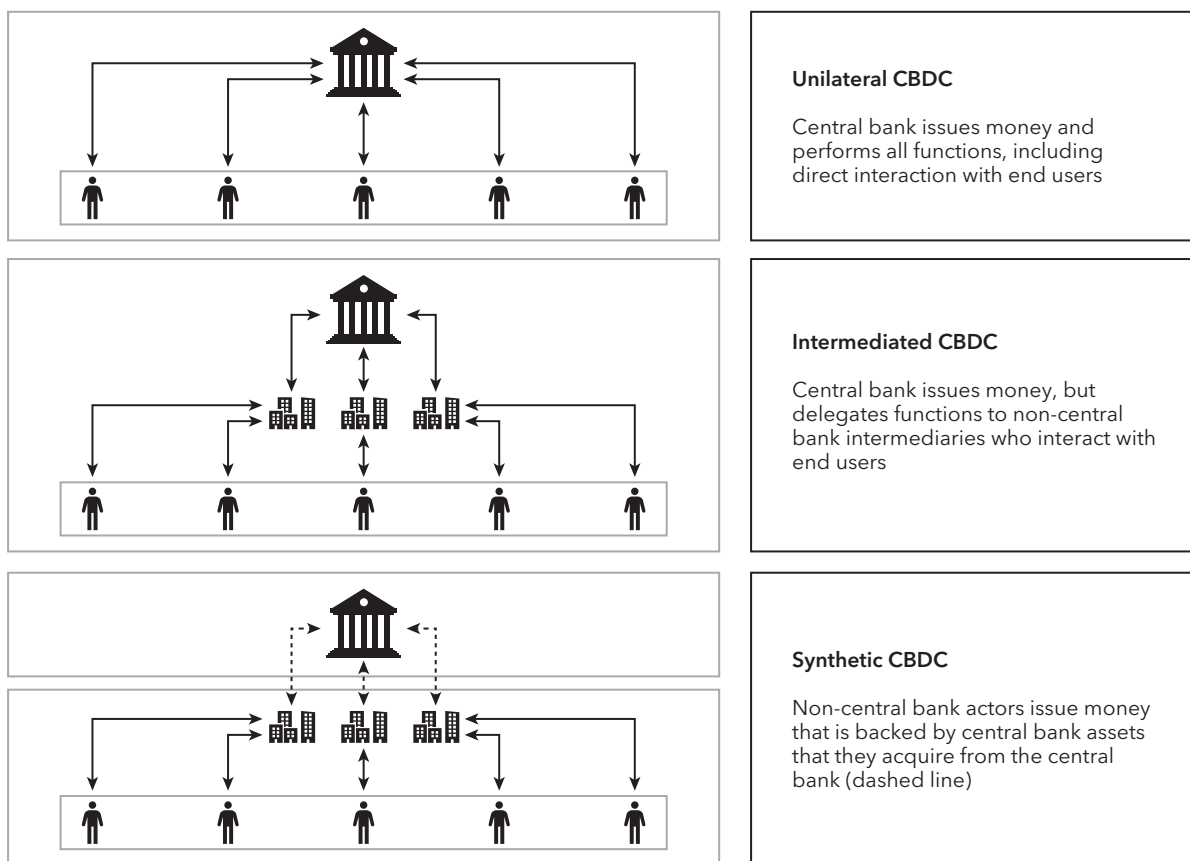
²⁷ For a discussion on how state-owned enterprises have developed in the recent decades, see Bruton and others (2014).

²⁸ For a discussion, see Kiff and others (2020).

²⁹ See Adrian and Mancini-Griffoli (2019, 2021), Auer and Böhme (2020), and Auer and others (2021).

³⁰ Recently, however, the Hong Kong Monetary Authority issued a whitepaper outlining an approach similar to sCBDC. Cash in Hong Kong SAR is currently also mainly issued by private institutes rather than the monetary authority. For more on this, see HKMA (2021).

Figure 2. Three Conceptual CBDC Operating Models



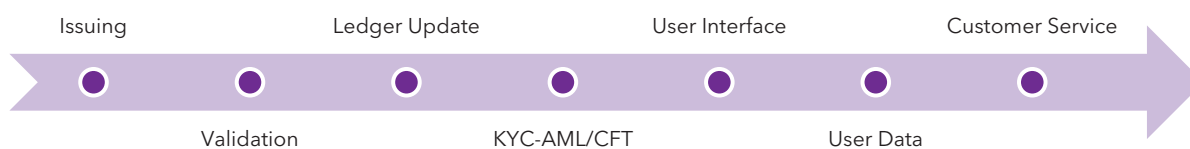
Source: IMF staff.
 Note: CBDC = central bank digital currency.

A. Central Bank and Private Sector Functions

The intermediated model can take different forms depending on how functions are distributed between the central bank and private intermediaries, as illustrated in Figure 3.

When discussing the distribution of functions between actors, it is useful to distinguish between the owner of the technical system necessary to carry out a specific function and the executor of the function itself. These are not always the same; indeed the system might be owned by the central bank while the

Figure 3. Functions to Be Carried Out in a CBDC Environment



Source: IMF staff.
 Note: AML/CFT = anti-money laundering/combating the financing of terrorism; KYC = know your customer.

function is carried out by a private company.³¹ For instance, the IT system that intermediaries use to monitor users of the Sand Dollar relating to AML/CFT is owned by the CBOB, which ensures a standardized approach. As mentioned above, delegating functions to private actors still requires regulation and monitoring.

Issuing is obviously a crucial function of all types of money. As discussed above, all central banks in the study currently explore models in which the CBDC are their own liability, just like cash. It is possible, though, for central banks to let a private company own the technical systems that enable CBDC issuance. For instance, in the Uruguay e-peso pilot, a private vendor owned and operated a technical system that converted pesos created by the central bank into e-pesos, effectively making the issuance of e-peso into a two-stage process.³²

Validation refers to validating a transaction. The concept is often associated with the validation that takes place in a distributed ledger technology (DLT) network but can also refer to more traditional processes including checking the user's identity, the authenticity of money, and the availability of funds.³³ In some cases, these functions are divided between the central bank and private entities. For instance, in the e-krona proof of concept, the central bank owns and operates a notary node that ensures money has not been spent before, while private intermediaries carry out remaining validations, such as checking the authenticity of e-kronas.

Each transaction entails a *ledger update* when users transfer holdings of CBDC between each other. A ledger is a database of records of monetary holdings but can be either centralized or distributed across a network. Updating the ledger means updating the records of CBDC balances after payments have been made. The centralized ledger, owned and updated by a single entity, is still the standard approach among central banks, whereas DLT is a potential new approach.

In the case of DLT, at least three alternatives exist. First, the central bank owns the infrastructure of the entire ledger and updates it (for example, the Bahamas Sand Dollar). Second, the central bank owns the ledger, but private intermediaries update it. And third, a private intermediary owns part of the ledger and updates that same part of the ledger, conditional on the central bank's approval (in the Swedish e-krona proof of concept, the intermediary can update the ledger after the central bank's notary node has checked that no double spending has taken place).

The remaining functions of Figure 3 concern the interaction with the end-users. *KYC-AML/CFT* refers to the process of implementing Know Your Customer (KYC) and AML/CFT requirements (for example customer due diligence measures) aimed at combating illicit flows. *User interface* denotes the means through which users can interact with and/or pay with their CBDC holdings, such as through applications on mobile phones. *User data* refers to the function of handling the personal data of users, and *customer service* captures the process of helping users connect to the CBDC, handling errors, and solving other issues.

Table 2 summarizes how functions are allocated between central banks and private sector actors in the six CBDC projects.³⁴ In some cases the distribution of functions may change when the project progresses from pilot to formal launch. For instance, the ECCB currently offers private intermediaries a ready-made application for users to interact with DCash wallets, but states that after a formal launch, intermediaries would develop their own user interfaces.

³¹ Importantly, systems ownership does not preclude outsourcing of certain aspects but it entails responsibility for the overall development, maintenance, and functionality of the system, including outsourced services. For a definition of system owner, see NIST (2021).

³² For more on potential operational risks of outsourcing central bank activities, see Kiff and others (2020)

³³ For an overview of DLT in payments, see BIS (2017) and Shabsigh and others (2020). DLT can be permissionless, meaning that anyone can join the network and partake in performing crucial functions, or permissioned, meaning there are strict requirements to joining the network. All central banks that are currently exploring DLT are focusing on the permissioned variant. For more on this, see Natarajan and others (2017).

³⁴ Private sector here includes state-owned enterprises and cooperatives. See Bruton and others (2014) for a discussion.

Table 2. The Distribution of CBDC Functions Between the Central Bank and the Private Sector

	Issuing		Validation		Ledger Update		KYC-AML/CFT		User Interface		User Data ¹		Customer Service	
	Owner	Executor	Owner	Executor	Owner	Executor	Owner	Executor	Owner	Executor	Owner	Executor	Owner	Executor
Bahamas														
Canada														
China														
ECCU														
Sweden														
Uruguay														

Color scheme: Central Bank Both Private Still Exploring

Source: Central banks and IMF staff.

Note: AML/CFT = anti-money laundering/combating the financing of terrorism; KYC = know your customer.

¹One option is to grant central banks access to data stored by intermediaries. This is the practice in China.

B. The Business Model of CBDC

The business model of CBDC is a key concern for both private firms and the central bank. If private firms are expected to carry out a function in the CBDC ecosystem, they will have to make a profit at least in the medium term. Similarly, though central banks are not-for-profit organizations, they will need to decide whether to seek cost-recovery for their expenditures of building the CBDC system. Central banks may also decide to subsidize the use of CBDC to increase adoption if supported by a particular policy goal.

Among the CBDC projects reviewed in this paper, there is almost universal consensus that the main business model for private intermediaries is fees on payments. The role of the central bank is seen as providing a free or low-cost platform on which private intermediaries can operate. None of the central banks favor allowing private intermediaries to gather payments data, which could be used for commercial purposes. The PBOC notes it does not charge intermediaries or users, and intermediaries cannot charge individual users in the e-CNY project. However, intermediaries have the choice of charging merchants. The PBOC views this as a substantial incentive for firms to enter the market, and keeping fees in check.

The BOC states the choice of business model is complex. One possibility is for the central bank itself to provide a basic CBDC payment function to the public, possibly but not necessarily charging a fee for using it. The Riksbank is also considering this approach.

The question of whether a central bank should charge intermediaries for using the CBDC system is also connected to the question of whether it anticipates recovering its development costs. There is a risk that if central banks collect fees, intermediaries will in turn pass the cost downstream and raise the price of payments, which may counter initial policy goals. The question of whether and how to cover costs remains an open question, and the BOC states this as one of its most important areas of research.

Staff at the Riksbank also state that charging intermediaries fees is difficult because of the current regulatory framework. Another issue is that charging fees would possibly contradict its commitment to offering payments as a public good. Revenues for the central bank would likely solely be in the form of seignorage.

While subsidizing the adoption of CBDC is currently not seen as a viable path, the Riksbank is discussing if it might subsidize the cost of developing certain functions that the private sector would not find profitable. Examples of this include increasing payments resilience and developing payment solutions for minorities.

4. Design Features

CBDCs can be designed in different ways with different characteristics and functions. We refer to these characteristics and functions as *design features*. Design features are more specific than the operating model, and CBDCs with the same operating model can still differ in their design features. CBDC designs are generally intended to support policy goals or mitigate risks that could arise from issuing CBDC. This section is divided by topic and ends by summing up design features of individual projects in Table 3.

A. Restrictions Aimed at Ensuring Financial Stability

Central banks engaged in CBDC projects have committed to not jeopardizing financial stability and avoiding any sudden shifts to the structure of the financial system.³⁵ The literature discusses the potential risk that the introduction of CBDC could create, including crowding out banks and facilitating bank runs.³⁶ In addition, the literature discusses different ways to mitigate these risks by either restricting CBDC balances or taxing the use or balances of CBDC above a threshold.³⁷

All CBDCs that are currently circulating, either as official currency or through a pilot, are designed with restrictions that limit the competitiveness of CBDC versus bank deposits. At the time of writing, however, only three of the six central banks in this study—the central banks of the Bahamas, China, and the Eastern Caribbean—have circulating CBDC. Other central banks are still analyzing these questions conceptually.

Limits on CBDC fall under two main categories: restrictions on remuneration of CBDC and quantitative restrictions on holdings and transactions of CBDC.

Restrictions on the Remuneration of CBDC

The Bahamas, China, and the ECCU currently do not pay interest on CBDC holdings. In all three cases, the reason is to limit CBDC competition with bank deposits. If there is no interest, CBDC can still be attractive as a means of payment, even while its attractiveness as a store of value (savings instrument) diminishes.³⁸

There is a potential policy trade-off between limiting competition with bank deposits and ensuring an effective transmission mechanism of monetary policy. Staff at the Riksbank, reflecting the past Swedish experience of low interest rates, point out that a zero percent interest rate on CBDC could limit the ability to carry out a negative interest rate monetary policy.³⁹ Also, the attractiveness of bank deposits versus CBDC would shrink with lower policy rates. A possible solution is a CBDC with an interest rate that is consistently lower than the policy rate. The Riksbank is investigating the legal issues related to paying interest rates (whether positive or negative) on CBDC.⁴⁰

An alternative discussed in the literature is to impose fees on transactions above a certain threshold, but so far none of the CBDC projects have tried this.

Quantitative Restrictions

All three active CBDC projects were designed with quantitative restrictions. The goal is to explicitly limit competition with bank deposits but also to foster financial inclusion. To lower the threshold to onboard new

³⁵ Central Banks and BIS (2020), G7 (2021).

³⁶ For example, see Kumhof and Noone (2018), Juks (2018), and Bindseil (2019).

³⁷ In particular, see Bindseil (2020).

³⁸ For more on this, see Agur and others (2022).

³⁹ For example, see Armelius and others (2018) and Armelius and others (2020).

⁴⁰ For a legal discussion on interest rates and CBDC, see Bossu and others (2020).

users, small CBDC holdings are allowed without the need for identification or other KYC procedures (see more in the section on Anonymity).

Without special arrangements, it is not possible to send money to a wallet that has reached its specified limit, and the sender will typically receive an error message when trying to do so. CBDC holdings may also be connected to a bank account to which excess holdings of CBDC may automatically be transferred. Such a function is currently under development in the Bahamas Sand Dollar.

Limits to CBDC balances may also help limit pilot programs. Uruguay limited both the number of users and the amount of total e-pesos each user could hold. This made the pilot more manageable, but also lowered risks of disruptions and to the reputation of the central bank (were something to go wrong).

The ECCB DCash pilot also plans to limit the total amount of DCash that can be created. For now, however, DCash is offered to meet demand. No decision has been made on when to set the limit or how high it should be, in part to meet unexpectedly high demand due to the COVID-19 pandemic and support the economic recovery.

The Riksbank is exploring different technological options that could allow quantitative restrictions, and has tested a payments card which carries a limited amount of e-krona.

B. Anonymity

Anonymity is one of the key traits of cash, and the rise of digital payments threatens the lawful or legitimate preference for anonymity by certain segments of the public or for certain purposes—such as buying a present for one’s spouse. Anonymity is also connected to financial inclusion: non-anonymous payment services often require forms of identifications that can be difficult or costly to obtain.

However, anonymity can also be used for illicit purposes and can undermine AML/CFT measures. Anonymity, therefore, poses a policy trade-off—the more anonymity, the larger the risk for illicit use.

All three active CBDC projects have chosen the same way to handle the policy trade-off between anonymity/financial inclusion and AML/CFT compliance. Their approach has been to provide a tiered selection of wallets with different levels of thresholds. Those with lower thresholds allow for greater anonymity. As a result, CBDC can more easily be rolled out into rural or disadvantaged areas where virtual identification can be difficult.

The use of tiered CBDC wallets thus gives rise to “policy synergies” between anonymity, risk-reduction (of bank runs), and financial inclusion.

C. Off-Line Capacity

The ability to pay when not connected to main telecommunication systems is important to increase resilience in crisis situations, such as during natural disasters and armed conflicts. Off-line capacity is hence linked to the policy goal of resilience and is especially important in disaster-prone or geopolitically tense areas. The PBOC also emphasizes that off-line functionality is important in areas with patchy telecom access, which also often correspond to areas of low financial inclusion.

In practice, off-line functionality has turned out to be complicated technologically.⁴¹ Further, the exact definition of off-line transactions differs. Often the term refers to being off-line from the Internet but still reliant on a local network, such as Bluetooth. But some events such as prolonged black-outs or electromagnetic disturbances might affect local networks as well.

The Bahamas considers off-line functionality to be vitally important but has encountered difficulties in achieving it. The pilot revealed that the planned solution of local off-line networks—built on introducing local redundancies to the main telecommunication system—did not fully achieve the policy goal. The

⁴¹ For a discussion, see Chohan (2021), Armelius and others (2021), and ECB (2020).

telecommunication towers required in the solution are vulnerable to the same weather conditions as the main telecommunication system. Also, the geographical reach of the local networks is limited, which makes it difficult to make payments between islands. Presently, the CBOB is working with its main contractor to identify alternative solutions. Staff at the CBOB state that the decision to explore alternative off-line solutions was the most significant change that resulted from the practical experience of the pilot.⁴²

The PBOC has tested different solutions, and reports that sufficiently safe and efficient off-line payments are now in place. These include hardware-based e-CNY wallets placed inside mobile phones, or held as cards that can make payments to another mobile phone wallet in physical proximity without Internet access. To reduce the effects of illicit tampering with the devices, which could lead to double spending and counterfeiting, each user can only perform a limited number of off-line payments before needing to go back online to access the main ledger. In addition, offline payments in e-CNY involve a variety of technologies, including digital signature and encrypted storage to further reduce risks.

The team working on the Swedish e-krona proof of concept has identified a number of potential solutions to establish offline functionality and is proceeding to test these. Participants have identified several challenges, such as how to prevent double spending and ensure the authenticity of e-kronas while off-line.⁴³

D. Cross-Border Payments Using CBDC

Central banks and international organizations are increasingly evaluating the use of CBDCs to enhance the efficiency of cross-border payments, which is generally considered costly and inefficient.⁴⁴ The G20 has instigated an ongoing collaboration between international organizations and national central banks to explore ways to further this goal, including through CBDCs.⁴⁵

Retail CBDC projects are carried out primarily with domestic purposes in mind, at least so far. Nonetheless, discussions on how CBDC could potentially be used in cross-border payments are ongoing. And technical experiments on wholesale CBDC for cross-border usage have been conducted for several years.⁴⁶ Adverse macroeconomic implications, such as increased currency substitution and vulnerability to financial shocks, are possible as retail CBDC become available across borders.⁴⁷ These potential risks, and means of mitigating them, are being discussed in the context of the G20 roadmap to enhance cross-border payments.

The six jurisdictions in this study are exploring cross-border issues carefully but largely on the side of their domestic considerations. Canada, China, and Sweden are represented in the Future of Payments Working Group, which stems from the G20 roadmap. In addition, the PBOC is also exploring how a retail CBDC, such as the e-CNY, can be used for cross-border payments, and has partnered with the BIS Innovation Hub and other national central banks in the multi-CBDC Bridge project—an experimental CBDC arrangement leveraging DLT to facilitate cross-border payments.⁴⁸

The PBOC states three principles for their ongoing work on cross-border payments for CBDC. The first is the principle of “no disruption,” which in practice means to avoid negative spillovers on the Chinese economy and that of other nations, such as significant currency substitution. The second rule is that any CBDC cross-border payments system must be compliant with the rules and regulations of all connected countries, including capital flow management measures. In addition, according to the PBOC, information

⁴² The tested solution relied on smaller local networks that were meant to act as backups to the main telecommunication system rather than independently of telecommunications.

⁴³ See also Sveriges Riksbank (2021b).

⁴⁴ BIS and others (2021).

⁴⁵ FSB (2020).

⁴⁶ For example, see BOC and others (2018) and BOT and HKMA (2020).

⁴⁷ For more on potential macrofinancial implications of cross-border use of CBDC, see IMF (2020a) and BIS and others (2021).

⁴⁸ BISIH and others (2021).

flows between countries should be improved to help authorities counter illicit use of money, including tax evasion. According to the third rule, cross-border payments should involve interoperability across domestic CBDCs or between domestic CBDCs and incumbent payment systems rather than a single CBDC used for transactions on both sides of the border. The PBOC thus prefers a system where domestic CBDCs are converted to other currencies as payments cross borders.

The Bahamas does not currently allow the Sand Dollar to be used outside its borders. It has stated that the Sand Dollar is exclusively intended for domestic purposes and that cross-border payments must take place through commercial banks in traditional non-CBDC Bahamian dollars. However, foreigners can own and pay with Sand Dollars when visiting the Bahamas after registering for an account with a low limit on both balances and monthly transactions.⁴⁹ Nevertheless, the central bank is planning to explore cross-border functionality for the Sand Dollar within the next three years.

Staff at the ECCB look favorably to using CBDC for cross-border payments, given the importance of trade and overseas remittances for the countries in the ECCU. The ECCB has begun discussions with other regional central banks regarding the interoperability with legacy payment systems and platforms to enable remittances and trade in the region. At present, however, the main priority is ensuring that DCash works for domestic purposes. That being said, as the ECCU consists of eight different nations, the DCash technically represents the first trial of a single CBDC used for cross-border payments, although within a monetary union and with the same central bank.

Staff at the six central banks have raised the following main hurdles to using CBDC across borders:

- *Technical interoperability*: The lack of coordination on technology and messaging standards in initial stages of development could imply that retrofitting CBDC for cross-border use will be costly and complex. Collaboration on the G20 roadmap may help, while decentralized forms of compatibility between different DLT systems may also be promising.⁵⁰
- *Legal and regulatory harmonization*: At present, all the jurisdictions have carried out their legal investigations based on their domestic legal systems. However, some harmonization may be needed regarding the treatment of data and privacy, tax and payments laws, and capital flow management measures.

E. Summary of Design Features

Table 3 summarizes the design features under consideration or deployed by the six central banks.

Table 3. Design Features of CBDC Projects

	Carry Interest or Not	Quantitative Restrictions	Anonymity	Offline	Cross-Border Payments
Bahamas	No	Yes	For lower tier	Yes/exploring	Future project
Canada	Undecided	Undecided	Undecided	Exploring	International collaboration
China	No	Yes	For lower tier	Yes	Experimenting/international collaboration
ECCU	No	Yes	For lower tier	No	Future project
Sweden	Undecided	Exploring	Undecided	Exploring	International collaboration
Uruguay	No	Yes	Yes, but traceable	No	Possible future project

Source: Central bank staff and published sources.

⁴⁹ It is possible, however, to integrate a Sand Dollar account with a bank account so that CBDC is exchanged into commercial bank money before making the cross-border payment.

⁵⁰ BIS and others (2021), Herlihy (2018).

5. Technology

CBDCs rely on technology, which must be appropriately selected to operationalize the policy goals discussed earlier. Even in an intermediated CBDC model, the central bank must build a core system for issuing CBDC and processing transactions. One of the great difficulties is making decisions while much of the technology is still developing and remains relatively untested. Central banks must decide where to acquire technology, if they do not build it in-house, and which technology best suits their purposes.

A. Technology Suppliers

A central bank typically needs to acquire technology from or partner with external vendors to develop proprietary solutions. So far, there are two main approaches to the technology supply question. The first is to choose a main contractor that supplies the technology and collaborates with the central bank to develop the CBDC. This “CBDC package solution” was chosen by the Bahamas (NZIA), the ECCB (Bitt), Sweden (Accenture), and Uruguay (Roberto Giori). In the case of Sweden and Uruguay, however, contractors were used to deliver a specific test solution and thus would not necessarily be relied upon to further develop, and potentially launch, CBDC.

In the second approach, the central bank relies to a greater extent on internal resources and has different contractors for different areas as necessary. This approach tends to be more onerous for the central bank in terms of internal capacity and resources, but also offers more control over the development process. Canada and China have chosen this path. The BCDU indicates that a second Uruguay CBDC pilot may likely be based on this approach to avoid relying on a single vendor.

Intermediaries can also be selected as development partners. The PBOC, for instance, has partnered with specific e-CNY intermediaries to develop payments solutions and functions that have been added to the e-CNY ecosystem.

B. Distributed Ledger Technology vs Centralized Technology

Distributed ledger technology (DLT), the best known of which is blockchain, has in recent years emerged as a promising alternative to technologies that are based on centralized ledgers. Central bankers are therefore faced with another technology choice.⁵¹ The choice is particularly difficult as DLT is still developing, and its capacity and suitability are being explored. Some pilots and proofs of concept are therefore testing DLT without necessarily expecting to select it for further development.

The experiences so far suggest that there is no universal case for DLT as the primary engine of CBDC, and jurisdictions have different views on the potential merits of the technology. The Bahamas and the ECCB have DLT-based systems, and staff from both central banks cite the security of the technology as valuable for their needs.

The PBOC, on the other hand, has tested DLT during its pilots and decided that its capacity to process transactions and store data does not meet its requirements. It is particularly concerned about e-CNY’s ability to handle days with very high levels of transactions, such as the “Singles Day” (November 11, China’s equivalent to Black Friday in the United States).

However, the PBOC has committed to what it refers to as a “hybrid architecture.” Thus, DLT is being used in the e-CNY system but only in limited areas where it is deemed to have an advantage over other technologies. Intermediaries can also base their activities on any technology, including DLT, and still function in the e-CNY ecosystem. This openness to different technologies is part of what the PBOC calls a “Long Term

⁵¹ See Kiff and others (2020), Auer and Böhme (2020).

Evolution System,” through which new features of technology can continue to be added to the e-CNY even though its core is a centralized ledger.

The e-peso did not rely on DLT, but BCDU staff acknowledge that a potential second e-peso pilot might test the appropriateness of DLT, or a hybrid system that incorporates DLT for particular purposes.

The BOC has not decided on technology but is carrying out multiple technological workstreams, including DLT. Its staff has expressed some skepticism about the suitability of DLT for central bank purposes but acknowledges that DLT can support some important functions. One possibility would be to combine different technologies to achieve different purposes.⁵²

The Riksbank is currently exploring a DLT-based proof of concept, but its staff stress that a potential future e-krona does not necessarily have to be built on DLT. A second e-krona proof of concept or pilot could thus be based on a different technology.

C. Summary of Technology Choices

Table 4 sums up the technology choices described above.

Table 4. Summary of Technology Choices

	Main Tech Contractor	DLT
Bahamas	NZIA	Yes
Canada	–	–
China	–	Hybrid
ECCU	Bitt	Yes
Sweden	Accenture	Testing
Uruguay	Roberto Giori	No

Source: Central banks and published sources.

Note: DLT = distributed ledger technology; ECCU = Eastern Caribbean Currency Union.

6. Legal Foundations for CBDC

CBDC⁵³ requires a legal framework that clarifies whether the central bank has the mandate to issue CBDC and what status it would have legally.⁵⁴ Existing legal frameworks were typically enacted in a pre-digital age, and investigating CBDC therefore also entails ascertaining whether law reform is necessary to ensure that a CBDC can be issued by the central bank.

The status of the six surveyed jurisdictions is summarized in Figure 4.

Figure 4. Status of Law Reforms in the Six Jurisdictions



Sources: Central banks and IMF staff.
Note: ECCU = Eastern Caribbean Currency Union.

To issue the Sand Dollar, The Bahamas enacted a revised legal framework, the Central Bank of Bahamas Act, in 2020. The currency issuance function is broadly worded, and the definition of “currency” explicitly includes not only banknotes and coins but also “electronic money” issued by the Central Bank.⁵⁵ Moreover, the Act specifically grants the Central Bank the power to issue currency in the form of “electronic money.”⁵⁶ To support this, the Act also grants the Central Bank regulatory powers to prescribe “the framework under which electronic money issued by the Central Bank...may be held or used by the public.”⁵⁷

Among the countries that have not yet formally issued a CBDC law, reform is still being investigated and prepared. For example, China is preparing for a general revision on People’s Bank of China Law (draft), which suggests that Chinese currency includes both physical and digital forms (e-CNY) and thus confirm the legal tender status of e-CNY.⁵⁸ The draft law provides the central bank with the broad power to plan, organize, and supervise the payment system and financial infrastructures. The Central Bank will have responsibility to coordinate the work on national financial security, with the goal of developing a cyber-resilient CBDC. In addition, the draft law explicitly prohibits and imposes fines on the production, sale, and circulation of “illegal CBDC.”

The ECCB has prepared a draft amendment to its central bank act. The draft amendment would establish the legal foundation of CBDC by extending the definition of “currency” to “digital currency.”⁵⁹ Further, it

⁵³ This section was written by Marianne Bechara, Wouter Bossu, and Akihiro Yoshinaga.

⁵⁴ On the analytical model for assessing those questions, see Bossu and others (2020).

⁵⁵ Central Bank Act of The Bahamas (2020). Sections 5(1) and 8(1).

⁵⁶ Central Bank Act of The Bahamas (2020). Section 12(7).

⁵⁷ Central Bank Act of The Bahamas (2020). Section 15.

⁵⁸ PBOC (2020). Articles 18 and 19.

⁵⁹ Eastern Caribbean Central Bank Agreement (Amendment) Order (2020), Article 2.

explicitly attributes legal tender status to digital currency and clarifies the central bank's sole right to issue digital currency.⁶⁰

In Sweden, the legal questions are currently being investigated in a government inquiry launched after a petition was sent to Parliament by the Riksbank in 2019.⁶¹ In parallel, the central bank is actively analyzing whether existing means of payment and legal mechanisms in Sweden would be fit for e-krona operations or whether new types of assets or legal mechanisms should be created by law.

Since it has decided not to issue a CBDC at this time, Canada is not currently looking into law reform. When Uruguay completed its six months e-Peso pilot in 2018, the legal framework was considered sufficient at the time for the central bank to carry out the testing without the need for legal amendments. Such amendments, however, would be necessary for an official roll-out of the e-peso, according to the central bank.

Surveyed central banks flagged several legal challenges (in addition to the challenge of legal harmonization mentioned in the section on cross-border payments) to issuing CBDC, as well as lessons that could be drawn from that process.

"Law follows technology": In many cases, the operating and even legal design of CBDC was initially driven by technological developments, often under the advice of consulting firms. Central banks are therefore recommended to initiate legal reflections very early in the process. This should go hand in hand with building sufficient internal legal capacity in central banks' legal departments.

Understanding the legal nature of CBDC: In many countries, this new form of money poses significant legal challenges under public and private law. In some countries, some fundamental issues still need to be decided, such as the legal nature and ramifications of issuing digital currency (for instance, rights of holders subsequent to the insolvency of authorized providers). Given the many legal complexities, several central banks relied on external counsel to develop the legal-regulatory framework for CBDC. Central banks should consider combining the abovementioned internal capacity building with a needs assessment for external counsel. This could go hand in hand with a close dialogue with financial intermediaries, in particular, to gain insights into for instance how they see CBDC impacting their business models.

Legal tender status: While central banks acknowledge that the technical means to receive CBDC in payment (such as devices or internet access) is not universal in their countries, most of the surveyed central banks nevertheless advocate granting legal tender status to CBDC. This approach could be possible under a fairly "relaxed" legal conception of legal tender status, with ample space for contractual derogations. That said, it is also acknowledged that without wide acceptance and circulation of CBDC, the reputation of the issuing central bank would be at risk. Against this background, a few jurisdictions have started a fundamental debate on the role of legal tender currency.

Flexibility and law reform in preparatory phase vs. final phase: Several central banks indicated that they saw no need for law reform in the pilot phase, but that law reform would be necessary for the final phase (roll-out). Maintaining this type of flexibility during the pilot phase may be useful for other central banks, in particular at a stage where CBDC is not yet issued as an actual liability of the central bank, and central banks may alter fundamental design features subsequent to the pilot.

Specific vs. general law reform: Modifying the central bank law and other laws only to strengthen the legal basis for CBDC issuance may be the fastest route. However, a few central banks chose to anchor these amendments into a broader reform of the central bank's charter to address other legal issues. This was the case in the Bahamas. Whilst such an approach may somewhat slow down the law reform process, it yields the benefit that other aspects of the central bank's legal framework can be strengthened in conjunction. Going forward, countries should assess whether CBDC-related law reform could be an opportunity to introduce other legal amendments.

⁶⁰ Eastern Caribbean Central Bank Agreement (Amendment) Order (2020), Articles 18(1) and 18(3).

⁶¹ SOU (2021).

7. Project Implementation

CBDC projects are generally large undertakings for central banks and need to be organized, staffed, and financed. The availability of resources differs across central bank, as does the importance of CBDC projects relative to other undertakings. Carrying out a pilot further requires planning and execution, supportive institutional structures, and investment in staff education, skills, and retention. A key part of a CBDC project is also to ensure that there is enough staff to identify and monitor operational risks.⁶²

This section investigates the different organizational paths taken by this paper's six central banks, the learning curve of staff engaged in CBDC, and the main challenges they have faced.

A. Organizational Changes at the Central Bank

Central banks investigating CBDC must decide whether to make formal organizational changes, or work with existing structures. Some have created new committees, divisions, or research centers.⁶³ Others have instead reprioritized the work of staff in existing divisions.

At one end of the spectrum, and reflecting the size of its undertaking, the PBOC first set up a specialized work team in 2014, but two years later created a new specialized institute, the Digital Currency Institute of the People's Bank of China (PBCDCI). The PBCDCI has set up subsidiaries across geographical areas to help organize the e-CNY pilots.

Similarly, the CBOB created a new unit devoted to developing the Sand Dollar but under the supervision of a policy steering committee made up of representatives from the different departments of the bank.

The decision to make formal organizational changes can also arise as work on CBDC advances. The BOC carried out a substantial part of its CBDC analysis by drawing on the resources of two departments—coordinated by a fintech senior officer—neither of which were exclusively devoted to CBDC. Then, in 2020, after presenting its official position on CBDC (see Box 1), the BOC formed a research team to investigate technology that would help build capacity for a successful CBDC launch; the team was also tasked with monitoring conditions that could trigger the need to proceed.

Likewise, the Riksbank started its e-krona project with a project team consisting of members from different departments. However, a new division was created in 2019 devoted specifically to developing its e-krona proof of concept. CBDC policy analysis, however, remains part of the payments department's general policy work. The two divisions work closely together.

In contrast, the ECCB has not initiated any changes in its organizational structure and instead draws personnel from across different departments at the central bank to form an internal working group. Similarly, the BCDU did not initiate any organizational changes while conducting the e-peso pilot.

B. Internal Staffing

The number of staff at central banks involved in CBDC projects varies mainly with the degree of outsourcing to private vendors. Another important factor is the size of the pilots undertaken by the central banks. For instance, the staff working on the Chinese e-CNY project grew from around 40 to around 300. Importantly, this number does not include private-sector employees that have been working in collaboration with the PBOC.

For the CBOB and the ECCB, both operating in smaller countries and teaming up with a main contractor, the numbers involved are considerably smaller. At its peak during the launch, the Sand Dollar employed 35

⁶² Khan and Malaika (2021).

⁶³ For a discussion on CBDC projects and central bank governance, see Bechara and others (2021).

people at varying levels of time commitment. Currently, 15 people work full-time on the Sand Dollar. The ECCB is currently managing its DCash project with 12 people, all of whom in addition have other duties. This has been possible thanks to considerable technical expertise from outside. The Uruguay e-peso pilot similarly employed five full-time and five part-time employees. Again, these numbers refer only to central bank staff, and the full amount of personnel involved on the private sector side is likely considerably larger.

Table 5. Number of Central Bank Staff Engaged in CBDC Projects in Late 2021

Central Bank	Number of Staff
CBOB, Sand Dollar	15
BOC	50
PBOC, e-CNY	300
ECCB, DCash	12
Riksbank, e-krona	20
BCDU, ePeso	0 (10 during pilot)

Source: Central banks.

Note: This table does not include private sector personnel. Further, it does not distinguish between those working full time or part time on the CBDC project. The reason is the difficulty in comparing the time spent by part-time employees who, in some phases of the project, may work more than full time. Part-time employed, therefore, often means that they have other tasks besides CBDC. BCDU = Banco Central de Uruguay; BOC = Bank of Canada; CBDC = central bank digital currency; CBOB = Central Bank of Bahamas; ECCB = Eastern Caribbean Central Bank; PBOC = People's Bank of China.

C. Organization and Design of Pilots

This section focuses on the organization and execution of pilots. Canada and Sweden have not launched pilots, so are not discussed in this section. The three main aspects of a pilot are its general organization, how users are recruited and what results they yield, and how those results are incorporated.

General Organization of Pilots

The first main pilot design factor is how limited it will be. Pilots can be limited in time by having a clear termination date communicated in advance. But they can also be limited in scope in terms of how many users can participate or how much money will be issued.

The second main pilot design factor is its goals and the ability to revisit these as the pilot progresses. For instance, central banks may choose to develop and test new functions after the initial launch. Pilots are also sometimes directly used to further specific policy goals, for instance, by being extended to certain areas to support economic development or recovery after a natural disaster.

The four pilots studied in this paper are described below in the order they were first launched.

Planning for the Uruguay e-peso began in 2016 and the pilot ran from November 2017 to April 2018. Compared to the other pilots in this study, this effort was more contained in time and scope. It was clear from the outset that the pilot would end after six months, and all e-pesos owned by test users at the end of the pilot would be cashed in and destroyed. Total issuance was set at 20 million e-pesos, and no more than 10,000 end-users could take part by downloading an app on their cell phones. The pilot was also contained in terms of functional involvement of the private sector: from the outset, the different functions of the pilot were distributed among, as well as funded and developed by, a group of firms that were primarily interested

in testing aspects of their respective technologies. Thus, the e-peso was not an open platform, and commercial banks were not involved.

The CBOB launched the Sand Dollar pilot in December 2019 after more than three years of research into CBDC and planning the pilot. When considering suitable test areas, the bank opted to first roll out the pilot in the Exuma District in the South East Bahamas. Usage of mobile phones is high in Exuma, and testing the pilot there was ideal to ensure as many test users as possible. To create a baseline for measuring progress, the CBOB conducted a survey of the level of financial inclusion and willingness of the population to adopt digital payments.⁶⁴

The pilot was rolled out to a second test area, the Abaco Islands, in February 2020. The Abacos infrastructure was severely damaged by a hurricane in September 2019, and the area was still recovering economically. The Sand Dollar pilot in this area, therefore, served a double purpose—to test off-line payments solutions as well as a means to support relief efforts and economic recovery.

In total, the Sand Dollar pilot included around 2,000 wallets, and around 35 persons at the central bank were involved in its launch. The COVID-19 pandemic made the execution of the Abacos tests more difficult but did not change the pilot plans.

The scale of the Chinese e-CNY pilot is unique. By October 8, 2021, over 123 million e-CNY wallets were held by individuals and around 9.2 million wallets were held by firms. To help organize such a large trial in different areas in China, the Digital Currency Institute of the People's Bank of China (PBCDCI) created several subsidiaries in Shenzhen, Suzhou, and Shanghai, and is considering creating more in other areas.

The PBCDCI has the main responsibility for planning and executing the e-CNY trials, but collaborates with local authorities, private intermediaries, and technology firms. So far, trials have been conducted in more than 10 cities and regions. The scale of the trials has allowed the PBCDCI to test both core technologies for raw payment processing but also for ancillary and add-on features such as identification, off-line payments, and programmability. Trials have increasingly been conducted in rural areas, following regional economic development goals.

The ECCB rolled out the DCash pilot to four countries in the ECCU in March 2021: Antigua and Barbuda, Grenada, Saint Kitts and Nevis and Saint Lucia. The pilot is scheduled to run for 12 months, after which all DCash are to be cashed in and destroyed. DCash has been issued on demand as the number of users grew, but the central bank announced that there would be a total limit on how much would be issued. The central bank initially stated that the pilot will be successful when DCash reaches 4,000 end-users and 35 merchants per country in the ECCU. But with experience, the ECCB has adjusted these goals to reflect differences between countries.

The ECCB altered the plan for its pilot because of two external events. First, the COVID-19 pandemic led to an unanticipated increase in demand for both DCash and online shopping. In response, the ECCB decided to expand the pilot to include online purchases using a web browser. Second, a volcano eruption in St. Vincent and the Grenadines also prompted the ECCB to accelerate the pilot in the affected area to help it recover by increasing access to payments.

In sum, the pilots of several jurisdictions were modified to address external events, thus highlighting the importance of a flexible approach.

Recruitment of Users for the Pilots

A CBDC pilot requires users willing to learn to use a new payments solution and trust it with their money. All central banks with pilots stressed the importance of information campaigns to recruit test users. In addition, financial incentives can be used. In the e-peso pilot, the BCDU's technology partner Roberto Giori paid for the information campaign to recruit test users and funded financial incentives: the first 1,000 users

⁶⁴ For a summary of the Exuma survey, see CBOB (2019).

received 1,000 e-pesos (approximately \$23) for free, and 20 awards of 1,000 e-pesos were granted to the most active users for each month of the pilot.

The PBOC similarly launched a series of lotteries in collaboration with local authorities offering free e-CNY, which could be spent at merchants also joining the pilot. The local authorities provided the funding for these lotteries.

In the Bahamas and the ECCU, central banks have relied to a great extent on public information campaigns that stress the convenience and safety of paying with CBDC compared to physical means of payment. Recently, however, the ECCB added the incentive to get a percentage of expenses rebated in DCash at the end of the day for payments made in DCash at registered merchants.

Results of Pilots

Pilots can identify which areas need more testing, potentially through new pilots or extensions of pilots. The BCDU concluded that a potential second Uruguay CBDC pilot would need to be based on different principles compared to the first, including multiple vendors, and the participation of commercial banks.

Results of a pilot can also be used to improve the pilot or an officially launched CBDC. Staff at the CBOB stress that the most important gain from the Sand Dollar pilot was to better understand the motivations for potential users to adopt CBDC and for firms to join the CBDC network as intermediaries. This motivated the central bank to step up its communication and educational efforts on the local level. Further, the pilot showed the importance of increasing interoperability with the retail banking system to make it easier for users to convert bank deposits to Sand Dollars. As mentioned earlier, the pilot revealed that the planned off-line payment solution did not work as intended, and was the one major revision of the pilot in the officially launched Sand Dollar.

The ECCB's pilot is still in its early stages, so results are considered preliminary. However, demand has been sufficiently strong that ECCB now believes that ending the pilot after the planned 12 months might impair the payments system. Therefore, it is considering formally launching the CBDC and extending access to all countries in the ECCU rather than ending the pilot.

The PBOC reports that it is so far very pleased with the results of the e-CNY pilot. It has enabled testing a wide variety of different technological solutions for various features, including off-line capacity (see the sections above on design features and technology), payments methods using facial recognition, and tap-and-go. Surveys among test users, and the public, on the progress of the e-CNY, are also reported as being very favorable.

D. Stakeholders and Public CBDC Communication

Potential stakeholders in a CBDC project include the potential users, but also private intermediaries, incumbents in the payments and financial markets, as well as government agencies, representative political bodies, and governments. Some government agencies with a need to facilitate payments to individuals, such as tax agencies, social welfare agencies, or in some cases ministries of finance, might in particular have a stake in improving payments methods through CBDC.⁶⁵

The introduction of CBDC requires approval that goes beyond the central bank. For instance, legal changes are often needed that are typically enacted by politicians in legislative bodies. Further, getting people to test, understand, and trust a CBDC pilot does not come automatically, and so without the buy-in of the public, there will never be a meaningful level of adoption. Therefore, communication with stakeholders is a key part of CBDC projects.

The CBOB, as mentioned above, stressed the importance of reaching out to potential user communities. The bank partnered with communication experts and marketing agencies, and the pilot and official launch

⁶⁵ For example, see IMF (2020b).

were accompanied by surveys and market research. The bank invited representatives of different industries to discussion forums to discuss what the Sand Dollar could mean for them. Specifically, the bank took time to promote to commercial banks what benefits the Sand Dollar could bring in terms of lower costs of handling cash and a potentially larger customer base.

The Bahamas government, and other government agencies, were supportive from the outset of the Sand Dollar project. A key potential benefit for government agencies is lower costs of handling public transfer payments to individuals. However, staff at the CBOB states that it would have been beneficial to have had more engagements with these stakeholders to ensure that digitalization efforts were more synchronized.

The PBOC and the ECCB also stress the importance of organized public information campaigns. In China, public information is extended by the PBOC but also by the private intermediaries which carry out face-to-face interactions with end-users. The ECCB partnered with market research agencies to better understand the public's needs and to receive real-time feedback as the pilot progressed. The e-peso was also accompanied by an educational campaign.

The BOC and the Riksbank, however, have not engaged in organized information campaigns. The Riksbank stresses that its communication strategy has been openness about its project rather than education or promotion. It has published regularly on its CBDC work, as well as participated in both national and international conferences, forums, and bilateral meetings with representatives of different stakeholders. The second e-krona report, published in 2018, was accompanied by a call for comments from stakeholders, which were published on the bank's website.

In 2019, the Riksbank sent in a petition to the Swedish Parliament to create a government inquiry into the future role of the state in the digital payments market - including assessing the pros and cons of a Swedish CBDC. Parliament approved the petition, and the inquiry was launched in 2021. This is an example of how central banks can directly solicit key stakeholders and elicit a policy response, in this case starting the process of potentially changing legislation to allow for the creation of a CBDC.

E. Major Challenges and Hindrances

Investigating, testing, and even launching CBDC comes with its challenges. The central banks studied in this paper raise several common themes.

Lack of precedents: Several central banks pointed out the difficulty of designing a project where there is little or no experience, nor established standards. However, prior research, even if conceptual, was of value to guide choices along the way. The central banks all emphasize the need to continue learning and experimenting.

Lack of resources: As demonstrated in this paper, CBDC projects are resource-intensive and become even more so as their scale increases. Thus, the PBOC raises resources as a constraint. Likewise, resource constraints are one of the key reasons why Uruguay has not yet launched a second e-peso pilot. Staff at the ECCB also stated that the financial cost of the DCash project has been one of the major obstacles to overcome.

Unwillingness to adopt digital payments among the population: Some jurisdictions mentioned that part of the population is suspicious about CBDC and digital payments in general. The CBOB has pointed out that part of the population still does not trust that their money is safe if converted to Sand Dollar and that they are concerned about privacy issues.

Legal issues: The need to make amendments or change laws and regulations is mentioned as one of the key obstacles by several jurisdictions.

Cyber security: The PBOC said that the risks from cyberattacks are substantial if the e-CNY becomes a crucial payments system. Creating an acceptable level of cyber security is one of the main challenges it sees.

Technological uncertainty: As technology is still developing, choosing the best technology is deemed a challenge. For instance, ECCB staff were uncertain whether DCash's DLT technology was sufficiently scalable to meet the demands of large-scale adoption. It is therefore open to considering another model.

F. Key Insights

Central bank staff gain experience and insights from running CBDC pilots and interacting with intermediaries and users. This section summarizes key insights raised by the staff at the six jurisdictions. Thus, these insights reflect the experiences of staff at individual central banks and are not necessarily immediately applicable in other contexts.

The importance of market research: Based on its experiences with the pilot and official launch of the Sand Dollar, the CBOB stresses the need to perform extensive market research to understand the needs of potential users.

Collaboration with participating private intermediaries: The CBOB underscores the need for the central bank to have strong collaboration and open communication with private firms that have face-to-face contact with the end-users. This point is also emphasized by the PBOC.

Technology neutrality: The PBOC is a strong proponent of neutrality. The e-CNY is designed as a hybrid system which, though its core is based on centralized technology, is fully compatible with DLT or other technologies that intermediaries choose to use. This reflects the PBOC's key recommendation that no technology is perfect and that being open to using different technologies is key. Similarly, the BCDU said that the simplest and most appropriate technology for the purposes of the CBDC should be favored, a principle that it followed when setting up the e-peso pilot.

Importance of cross-border payments: The PBOC stresses the importance of exploring cross-border payments with CBDC and adhering to the principles of "no disruption, compliance, and interoperability."

The anonymity/privacy trade-off: The PBOC emphasizes the need to manage the tension between anonymity and privacy, but that full anonymity for all transactions cannot be considered.

Allowing the public access to information on CBDC: The Riksbank highlights the importance for a central bank to be open about its work on CBDC. The first reason is that issuing CBDC is fundamentally about how to organize a society's payments system and therefore concerns everyone. The second reason is that understanding CBDC can take a long time and the process of communicating with the public (and decision-makers) should begin early in the process.

The importance of non-technical aspects: The BCDU stresses that a CBDC is not only a technical process but also a cultural one. The introduction of CBDC will have to be guided by careful knowledge about the cultural aspects of users and preferences for the characteristics of money.

8. Conclusions

This paper discussed six CBDC pioneer projects. It illustrated the importance of individual country context and policy goals for the design and implications of CBDC. Just as there is no universal case for CBDC, there is no universal design or recipe to implement CBDC.

CBDC is still in its infancy, and there are still open issues as well as commonly identified obstacles. Open issues referred to by several jurisdictions include the nature of sustainable business models that will ensure cost recovery and provide sufficient incentives for private sector participation. Other issues have to do with pushing the boundaries of innovation to allow for important features such as off-line capacity. The choice of technology is also frequently highlighted, including the use cases and limits of DLT. Key difficulties going forward include making choices in a very new and rapidly evolving field, as well as costs associated with the development process.

A new trend among some of the jurisdictions in this study, spearheaded by the PBOC, is a pragmatic view of technology. The choice between centralized and distributed technology does not need to be either-or. And central banks could adopt CBDCs that utilize different technologies for different ends.

While individual country contexts remain important, there are also areas of convergence. All central banks have explored the intermediated operational model. Countries are seeking a balance between preserving key aspects of the traditional monetary and financial system while at the same time updating the role of central banks in the digital era. Relatedly, all CBDCs currently in circulation have design characteristics that limit competition with bank deposits.

Examples of policy trade-offs were evident during the discussions, but policy synergies were also identified. The relationship between anonymity and illicit use of money, for example, presents a policy trade-off, but there are policy synergies between anonymity, risk reduction, and financial inclusion. Managing policy trade-offs and leveraging policy synergies could be a potential area of increased central bank attention in the future.

Pilot designs differ among the jurisdictions from strictly limited in time, scope, and goals to more open-ended. Pilots are also used as policy tools. The exact dividing line between an open-ended pilot and an officially launched CBDC is therefore not always clear-cut, especially since an officially launched CBDC can continue to be upgraded and developed after launch. To some degree, a pilot could therefore lead to a “soft launch.”

CBDC exploration is still in an early stage, and not all country experiences can be easily ported abroad. There are still open questions, and CBDC remains an uncharted territory, raising challenges as well as opportunities. Increased international information-sharing of insights learned from individual CBDC projects and cooperation on policy and design issues will be important going forward. This paper represents an early contribution to this ongoing process.

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