Implications of Central Bank Digital Currency for Monetary Operations

Tansaya Kunaratskul, André Reslow, and Manmohan Singh

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Acronyms/Glossary

CBDC ..... Central Bank Digital Currency

CiC ..... Currency in Circulation

GDP..... Gross Domestic Product

NBC ..... National Bank of Cambodia

NBFIs ..... Nonbank Financial Institutions

OMOs..... Open Market Operations

RRs ..... Reserve Requirements

SFs..... Standing Facilities

Introduction

As central banks around the world contemplate issuing central bank digital currencies (CBDCs), an important policy question arises: how will monetary policy be affected? This question requires a two-part answer. The first concerns the transmission of the monetary policy stance to the broader economy—output and inflation. Views are provided in the IMF Fintech Note and CBDC Handbook Chapter on "Implications of CBDCs for Monetary Policy Transmission" by Das and others (2023). This Fintech Note aims to address the second part of the question, namely how the introduction of CBDCs would affect monetary operations—the process through which central banks use different instruments to manage the demand for and supply of reserves to achieve a desired stance of policy. It is crucial for central banks planning to introduce CBDCs to anticipate any implications for monetary operations and improve their operational framework to address any potential challenges in advance, as such difficulties could undermine central bank credibility and affect inflation expectations.

This Fintech Note analyzes the implications of CBDC issuance based on three scenarios: CBDC substituting for cash, commercial bank deposits, and reserves. The likelihood of each scenario depends on CBDC design features, such as who can access CBDC, limits on CBDC holdings, and remuneration of CBDC. In addition, market developments would determine adoption. For example, increased demand for tokenized deposits and tokenized assets could increase the demand for a wholesale CBDC as settlement asset and thus induce substitution from reserves to CBDC.

The analysis focuses on the balance sheets of the central bank, the banking sector, and the nonbank sector to illustrate the effects on the supply of and demand for reserves and short-term interest rates. Each of the three scenarios has different balance sheet effects. In the first scenario, where CBDC substitutes for cash, the implications for interest rates are more limited, although central banks may find it more challenging to forecast the liquidity in the banking system. The second scenario is more likely to affect monetary operations since commercial banks would lose reserves as bank clients substitute deposits for CBDC. In the third scenario, where commercial banks substitute reserves for CBDC, the implications for operations depend on the relative difference between CBDC and reserves.

This note then discusses how monetary operations can be calibrated to respond to the new environment with CBDC. In most cases, CBDC is not expected to overly constrain operations. In the first and second scenarios, central banks may need to upgrade their liquidity forecasting, introduce facilities to fine-tune the daily provision of liquidity, or temporarily adopt operational regimes less prone to liquidity shocks such as by fully meeting market demand for reserves at a fixed price. In the second scenario, when the short-term interest rates deviate from the target level as a result of CBDC, central banks can provide liquidity using monetary policy instruments to ensure the rates can adjust back to the target level. Finally, in the third scenario, central banks should ensure interoperability and allow banks to freely convert CBDC into reserves at par to prevent market price distortions and undesirable liquidity fragmentation.

Potential adverse impacts can also be managed through careful CBDC design. While the design of CBDC should primarily focus on serving its key policy objectives, central banks should nevertheless consider how the key design features can be further tailored to ensure their ability to conduct monetary operations effectively. For example, central banks can adjust access criteria or impose holding limits to

dampen banking disintermediation effects that could arise from the second scenario. In the third scenario, treating CBDC as equal to reserves such as counting CBDC toward the reserve requirement or remunerating CBDC-like reserves in a floor system could also help facilitate monetary operations.

It is important to recognize that this note is largely rooted in conceptual analysis, bolstered by extensive experience in monetary operations. As additional countries roll out CBDCs, the findings will be revised to reflect concrete lessons and practical experiences.

This note begins with a primer on monetary operations, proceeds to establish three scenarios of CBDC substitution for other forms of money, and subsequently examines the potential impact of each scenario on monetary operations. It then proposes changes to operations and CBDC design to help restore a desired monetary policy stance. Also, the operational implications related to the regimes of exchange rate and monetary targeting are briefly discussed.

A Primer on Monetary Operations

Central banks have varying objectives, but their common long-term policy goal is to achieve price stability. To attain this goal, they may adopt different monetary policy regimes, including inflation targeting, exchange rate targeting, and monetary targeting. Currently, most major advanced economies and emerging markets and developing economies have adopted an inflation-targeting regime, while many small open economies with a high reliance on international trade and investment opt for exchange rate targeting. Monetary targeting, however, has become less popular.

Monetary operations are employed to implement these monetary policy regimes. Monetary operations consist of four elements: (1) *objective* such as price stability, which establishes the medium-term goal for which central banks are held accountable; (2) *intermediate targets*, which assist central banks to calibrate their policy stance—for example, if a key indicator exceeds the intermediate target, monetary policy is typically tightened; (3) *operational targets*, which are variables that central banks control in the short term to satisfy intermediate targets over a longer horizon; and (4) *monetary policy instruments*, which are tools directly controlled by central banks to satisfy operational targets. Figure 1 provides stylized examples of the four elements of monetary operations for each monetary policy regime. Some countries adopt hybrid regimes which combine flexible inflation targeting, managed exchange rate floats, and a degree of capital controls.

Figure 1. Monetary Policy and Operations Frameworks

	Objective	Intermediate Target	Operational Target	Monetary Policy Instruments
Inflation targeting	Price stability	Inflation expectations	Interest rates	• Open market operations • Standing facilities • Reserve requirements • Foreign exchange interventions
Exchange rate targeting		Exchange rate	Exchange rate	
Monetary targeting		Broad money	The growth rate of base money	

Source: Authors' elaboration based on various other framework summary tables.

In an inflation-targeting regime, the central bank sets an explicit inflation target. The central bank sets a short-term policy rate as the operational target and uses a variety of monetary policy instruments to manage banking system liquidity, thereby ensuring that short-term market rates remain close to the policy rate. In addition, the central bank relies on forward guidance and other public communications to guide inflationary expectations as well as future interest rates, thereby influencing the shape of the yield curve.

In an exchange rate-targeting regime, the central bank targets a nominal exchange rate against a single foreign currency or a basket of currencies to stabilize the domestic price**.** The central bank conducts foreign exchange market interventions, such as buying and selling foreign currencies, to influence the exchange rate. It may also set its policy rate to manage demand for its currency relative to foreign currencies. The regime is more common for countries with high reliance on trade, and the prices of exports and imports largely determine domestic price levels.

In a monetary-targeting regime, the intermediate target is typically the growth rate of a broad monetary aggregate such as M2. The operational target is usually the growth rate of base money or M0, which comprises of reserves and currency in circulation (CiC) but can also be the overnight interest rates. This regime relies on a stable relationship between the targeted monetary aggregate and key economic variables, such as inflation and output. The central bank monitors and adjusts the money supply to meet the growth target.

Each regime relies on one or several monetary policy instruments to achieve the operational target. The instruments involve counterparties, primarily commercial banks, to serve as key intermediaries between the central bank and the broader economy, facilitating the transmission of monetary policy (King and Mancini-Griffoli 2018). The instruments typically involve payments in, or loans of, central bank reserves made to the counterparties through their deposit accounts held at the central bank.

- **Open market operations (OMOs)** involve the central bank providing liquidity to the market by lending against collateral through repurchase agreements (repo) or purchasing assets from the market, absorbing liquidity by taking deposits, conducting reverse repo, or issuing securities such as bonds/bills. OMOs are conducted at the initiative of the central bank (Gray and Talbot 2006).[1]
- **Standing facilities (SFs)** are lending and deposit facilities available on demand at the initiative of the central bank's counterparties. The lending facility allows banks to borrow additional reserves against collaterals, and the deposit facility allows banks to deposit funds (Gray and Talbot 2006).
- **Reserve requirements (RRs)** are a share of financial institutions' deposits or eligible assets required to be held as reserves with the central bank over a calculation period. RRs influence demand for reserves, short-term interest rates, and support the stability of the financial system. RRs are usually applied to commercial banks, but in some cases also nonbank financial institutions (NBFIs) (Baliño and Zamalloa 1997; Gray and Talbot 2006; Della Valle, King, and Veyrune 2022).
- **Foreign exchange interventions** involve the central bank buying or selling foreign currencies to steer or stabilize the value of its domestic currency in the foreign exchange market. Foreign exchange interventions result in the changes in the supply of reserve balances and the central bank usually conducts other market operations to ensure there is an appropriate amount of liquidity in the system to meet banks' demand.

When targeting short-term interest rates—as in inflation-targeting regimes, and potentially also in exchange rate– or monetary–targeting regimes—two major operational systems are possible. One is the corridor system, and the other is the floor system.[2] The corridor system can further be distinguished into two alternatives. Although all share similarities, they also have distinct features.

In a corridor system, the central bank sets an upper (the ceiling) and a lower bound (the floor) for short-term interest rates. The central bank uses SFs to define the bounds through lending and deposit rates and OMOs to further manage reserves. The central bank can provide just enough liquidity to satisfy

[1] In addition to these market instruments, central banks can use more unconventional tools, such as quantitative easing. Quantitative easing involves large-scale purchases of assets, such as bonds and securities, from the private sector with the objective of stimulating the economy especially during crisis times. In addition, some central banks periodically conduct outright asset purchases to maintain the bonds outstanding in their portfolios.

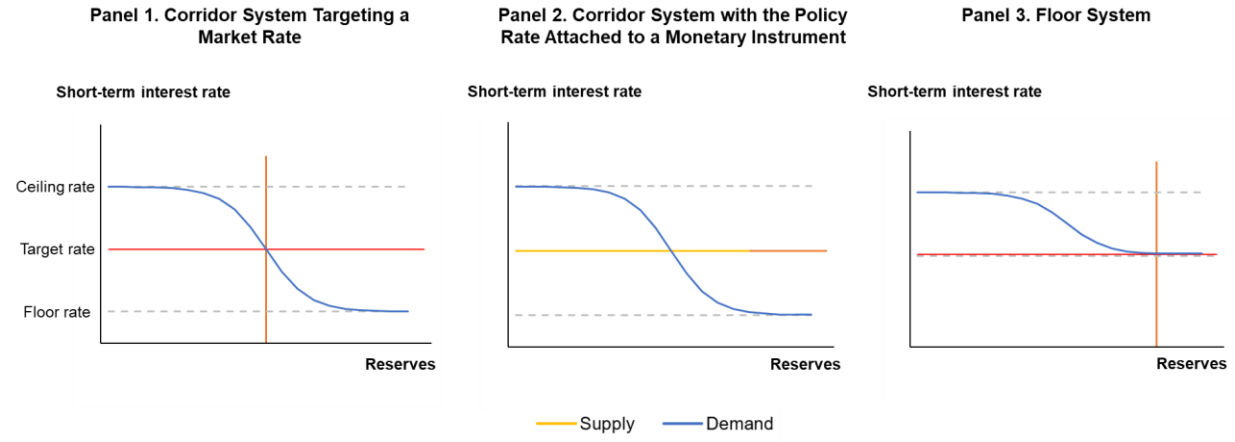
[2] Other systems and hybrid systems are also possible, and the particular design of the implementation can make two systems in the same "family" distinct or make different systems have similar characteristics. See, for example, Brandao-Marques and Ratnovski (2024) for how a narrow corridor can have floor characteristics.

the operational target within the corridor or offer liquidity at a fixed policy rate on a full allotment basis. The former necessitates highly accurate and frequent liquidity forecasts (King and Mancini-Griffoli 2018).

In a floor system, the central bank provides ample reserves to the banking system, ensuring that short-term interest rates stay close to an interest rate paid on excess reserves or the floor rate. This approach allows the central bank to increase the supply of reserves as needed without pushing market short-term rates below the policy rate. After the global financial crisis in 2008, many central banks, especially in developed markets, transitioned from a corridor to a floor system by flooding the system with liquidity by large asset purchases, which consequently pushed the short-term rates close to the floor rate (King and Mancini-Griffoli 2018).

Figure 2 provides stylized examples of the corridor and floor systems, and further breaks down the corridor system. The demand for reserves is downward sloping, whereas the supply of reserves is vertical because the central bank is a monopoly supplier of reserves and can choose a specific level to supply. As shown in Figure 2, panel 1, under the corridor system, the central bank calibrates the supply of reserves to intersect with demand at the desired target rate. If the central bank implements full allotment for reserves at a fixed policy rate in Figure 2, panel 2, the supply curve of reserves becomes horizontal. Meanwhile, the target rate is set at the floor level in a floor system, as shown in Figure 2, panel 3.

Figure 2. Stylized Corridor and Floor Systems



Source: Authors' elaborations based on King and Mancini-Griffoli (2018).

In both systems, the central bank needs to forecast autonomous factors affecting the supply of reserves and estimate the demand for reserves at the policy rate level to calibrate the volume of its operations. Liquidity forecast involves determining changes in the central bank's balance sheet components and assessing the appropriate level of reserves needed to stabilize the short-term interest rates at the policy target level. Conducting the forecast is especially relevant in a corridor system targeting short-term interest rates where frequent forecasting may be required to conduct daily (if not intraday) fine-tuning operations. Autonomous factors are elements affecting reserves that lie outside the central bank's direct control, necessitating the use of forecasts. For most central banks, the main autonomous factors include CiC, net government balances, and net foreign assets (Gray 2008). CiC is a physical form of central bank money, typically in the form of notes and coins, accessible by retail users and financial institutions. The quality of the forecast would ultimately depend on accurate and timely data, as well as predictive models.

Implications of CBDC for Monetary Operations

CBDC is a central bank liability, similar to reserves or cash (also referred to as CiC).[3] As such, the degree to which CBDC substitutes for other forms of central bank money could affect monetary operations. The economic concept of substitution refers to exchanging a good or service with another in response to changes in relative price, income, and other factors. This note explores the substitution of different forms of money—namely CBDC, cash, reserves, and bank deposits. Individuals or entities may choose to hold and transact one form of money over the other based on various factors such as convenience, returns, costs, safety, and liquidity preferences.

Three scenarios are relevant to monetary operations. First, CBDC can, to some degree, substitute for cash to the extent that retail users wish to switch from physical to digital central bank money. Second, CBDC can substitute for some of the commercial bank deposits held by households, firms, or NBFIs. In turn, this would affect the amount of reserves held in the banking system. Third, CBDC can substitute for central banks reserves directly if commercial banks settle interbank payments in CBDC instead of reserves held in traditional real-time gross settlement systems. The first two scenarios are often referred to as "retail CBDC," while the third scenario is referred to as "wholesale CBDC."[4]

This section analyzes the potential effects of CBDC on monetary operations based on the three scenarios. First, the section discusses the basic assumptions and conditions that could lead to each scenario, as well as balance sheet implications. Second, it analyzes the potential effects of CBDC on short-term interest rates. Third, it considers how the central bank could react—by either adapting operations or altering the design of CBDC to address the potential adverse implications on monetary operations. The analysis focuses on the inflation-targeting regime operating either a corridor or floor system. The section ends with reflections on how messages change—if at all—under the exchange rate or the monetary-targeting regimes. While the note examines the implications on monetary operations through various scenarios and regimes, it does not assess the suitability of each scenario. The appropriateness of each scenario depends on a country's specific circumstances, level of preparedness, and objectives in introducing a CBDC.

Three Scenarios of CBDC Substitution

As introduced in the previous section, the three main possible scenarios include CBDC substituting to some degree for cash, bank deposits, or central bank reserves. For all scenarios, it is assumed that other forms of money would be substituted by CBDC at par and largely on demand. Also, some basic design features of CBDC are likely to favor one scenario over another. These include (1) *access*—who can hold and transact in CBDC; (2) *remuneration*—expected returns from holding CBDC; and (3) *holding limits*—maximum thresholds on CBDC holdings. If CBDC is available primarily to retail users, is not remunerated, and has low limits, it is likely to substitute for cash. If CBDC is available also to a wider group in the nonbank sector—households, firms, and NBFIs—is remunerated, and has higher limits, it may substitute

[3] As such, it would from a statistical perspective be part of the monetary base or M0.

[4] A retail central bank digital currency (CBDC) is used by the general public, whereas a wholesale CBDC is typically used for transactions among banks and other financial institutions.

more significantly for bank deposits. Finally, CBDC, if available only to commercial banks with very high or no limits (and may or may not be remunerated), it could substitute for reserves.

Nevertheless, these scenarios are not mutually exclusive, as a single design of CBDC could lead to the simultaneous occurrence of multiple scenarios in practice.[5] Substitution is likely for more than one competing form of money. The degree to which cash, deposits, or reserves are substituted is what matters for monetary operations. Furthermore, many other CBDC design features and external factors such as the level of financial inclusion and the development of financial markets can also influence the degree of substitution. Box 1 provides more details on each scenario and the conditions for when they are likely to occur.[6]

Box 1. Further Details on the Three Scenarios of CBDC Substitution

- ***Scenario 1—CBDC substituting for cash*.** Cash is mainly used for large-volume, small-value retail payments, and many central banks envision a CBDC design targeting the same use case. A scenario where CBDC is mainly substituting for cash is more likely in contexts where cash is the predominant means of payment and financial inclusion is low. In jurisdictions where cash usage is already at a low level, central banks might also opt for a CBDC design with cash-like features such as being widely and publicly accessible, carry zero interest, and have small transaction caps, in order to maintain the presence of central bank money.[1]
- ***Scenario 2—CBDC substituting for bank deposits*.** Bank deposits, a private form of money, are used for both small- and large-value payments, and they are commonly used as store of value. Under this scenario, CBDC is assumed to be accessible to individuals and businesses with bank accounts. When depositors substitute deposits with CBDC, banks will need to exchange reserves or collateral for CBDC. Furthermore, banks might adjust their demand for cash, CBDC, and reserves in response. Depositors may find holding CBDC attractive for various reasons and could substitute a portion of their deposits for CBDC when they make portfolio allocation decisions (Gross and Letizia 2023). For example, CBDC may allow depositors to make payments more conveniently in an increasingly digitalized economy. Also, if under a banking crisis, depositors may be more inclined to substitute bank deposits with a risk-free CBDC, regardless of the remuneration rate of the CBDC.
- ***Scenario 3—CBDC substituting for reserves*.** Some central banks are investigating technology upgrades for their real-time gross settlement systems, while some others consider a CBDC system to sit alongside the current systems. Under this scenario, it is assumed that CBDC will not fully replace reserves but rather complement them. In addition, it is assumed that access is provided to financial institutions with reserve accounts, varying degrees of remuneration depending on a current interest rate imposed on reserves, (*continued*)

[5] The attractiveness of CBDC relative to, for example, cash and bank deposits would depend on design features such as perceived safety, ease of access, convenience, remuneration, technological innovation (such as programmability), cost of use, privacy, and anonymity. Moreover, wide acceptance of CBDC is also critical (Tan 2023). Some papers try to model and estimate the relative demand for different forms of money, but correctly capturing user preferences is challenging (see, for example, Agur, Ari, and Dell'Ariccia 2022; Gross and Letizia 2023).

[6] For details about motivations for CBDC exploration, see also Soderberg and others (2023).

and very high to no caps for CBDC transactions. Financial institutions are assumed to substitute reserves for CBDC when they need CBDC to settle their financial obligations which cannot be effectively processed through a traditional real-time gross settlement system through reserve accounts. Some potential use cases of CBDC include facilitating atomic delivery-versus-payment settlement for tokenized securities, serving as a settlement asset for tokenized deposits, enhancing cross-border wholesale payments, or providing resilience to real-time gross settlement systems as a backup, 24/7 payment system.

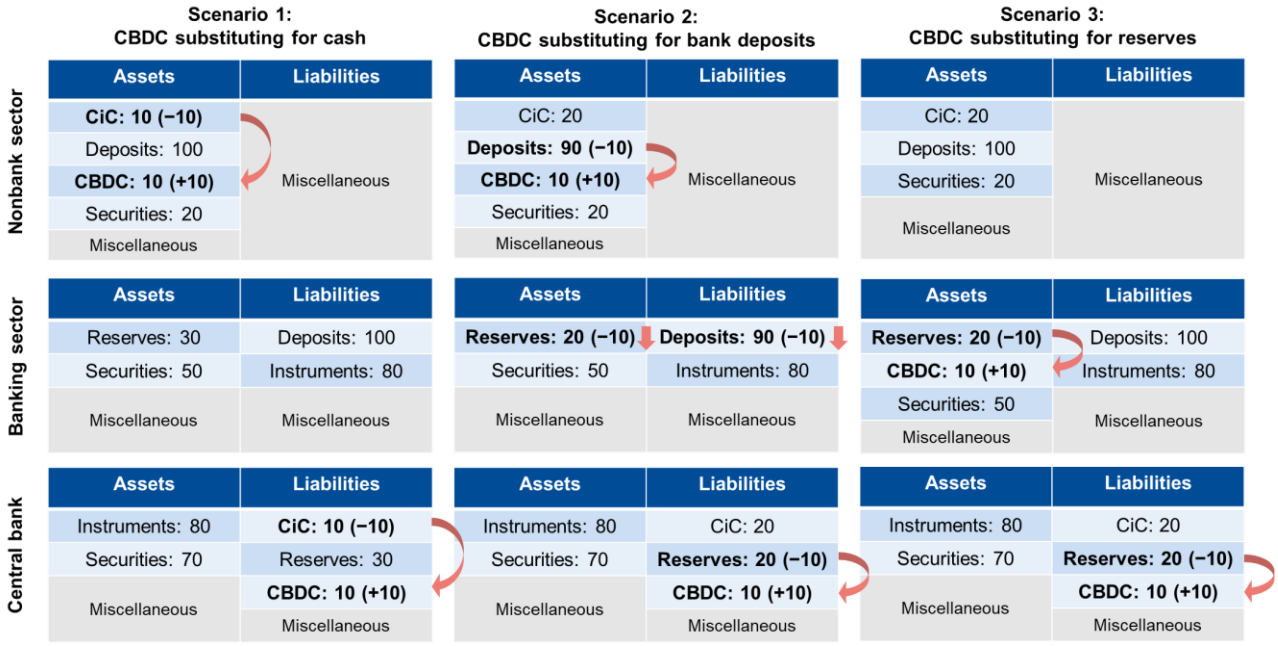
In addition, Scenario 3 can occur to support Scenario 2 when banks serve as distributors of CBDC to households and businesses. This situation is likely if reserve substitution can only occur during the central bank's operating hours, and banks need to hoard CBDC balances in advance to accommodate CBDC demand from households and businesses during off hours.

[1] While central banks might opt for cash-like CBDC designs, many central banks have committed to ensuring the continued safety and availability of cash (see, for example, Bank of England and HM Treasury 2023; Bowman 2023).

Each scenario has different initial effects on reserves, CiC, and bank deposits. Figure 3 shows the effects through stylized balance sheets of the central bank; the nonbank sector that includes households, firms, and NBFIs; and the banking sector.[7] Scenario 1 assumes that the nonbank sector substitutes 10 units of cash for 10 units of CBDC. This substitution is reflected in an identical change in the central bank's liabilities composition. In Scenario 2, the nonbank sector substitutes 10 units of bank deposits for CBDC. Commercial banks thus draw down their liabilities and reserves by the same amount of 10 units. As a result, the commercial banks' balance sheet shrinks, yielding a lower exposure of the banking sector to the central bank. Correspondingly, 10 units of CBDC appear on the central bank's balance sheet while reserves shrink by the same amount. In Scenario 3, commercial banks substitute reserves for CBDC, requiring the central bank to update its liability structure correspondingly. In addition to the initial direct effects presented in Figure 3, further indirect effects are possible, as later discussed.

[7] See also Abad, Barrau, and Thomas (2023) for an overview of the aggregated balance sheets in the economy; Armas and Singh (2022) for how different forms of digital money affect the balance sheets; and Malloy and others (2022), Lukonga (2023), and Caccia, Tapking, and Vlassopoulous (2024) for different scenarios for when CBDC replaces cash, bank deposits, and reserves.

Figure 3. Balance Sheet Analysis by Different CBDC Substitution Scenarios



Source: IMF staff calculations.
Note: The figure shows stylized simplified balance sheets in the economy. Instruments refer to central banks' monetary policy instruments such as open market operations and standing facilities and show the net position between the central bank and the banking sector. Miscellaneous contains various other objects on the balance sheets ensuring that the value of the assets and liabilities match. Numbers illustrate the changes in the balance sheet components within each scenario and not relative to the other scenario. The numbers in the parenthesis reflect the changes while the other numbers reflect the state after the change. CBDC = central bank digital currency; CiC = currency in circulation.

Effects on Short-Term Interest Rates

Scenario 1 (CBDC substituting for cash) is unlikely to affect short-term interest rates significantly but may complicate liquidity forecasting. As shown in Figure 3, the substitution of cash for CBDC would not directly affect reserve balances and the balance sheets of the commercial banks, thereby limiting its impact on interest rates. However, CBDC should nevertheless be considered an additional autonomous factor when forecasting liquidity (Armas and Singh 2022). Given its digital nature and the ease with which it can be held, demand for CBDC could be more volatile and uncertain than that for CiC, making liquidity forecasting more challenging.[8]

Scenario 2 (CBDC substituting for bank deposits) is likely to affect short-term interest rates initially since both the demand for and supply of reserves are affected. Figure 3 shows that reserve balances decrease when depositors substitute some bank deposits for CBDC. The decline of reserves comes from a leftward shift of the supply and demand curves of reserves, as shown in Figure 4. The magnitude of the shifts corresponds to the degree of substitution and adoption of CBDC.

[8] Because of its digital feature, CBDC could also increase the velocity of money (see, for example, Lukonga 2023), potentially affecting the money supply, the price level, and ultimately interest rates. However, the effects are not likely to be substantial, as the substitution from cash would have to be very large and the "velocity effect" would also have to be very large to have a material impact on interest rates.

Following the initial direct effects from the introduction of CBDC, additional indirect effects may arise because of subsequent adjustments in demand for reserves, which can affect liquidity conditions within the banking system. Currently, banks demand reserves to facilitate interbank payments, to satisfy regulatory requirements such as RRs or high-quality liquid assets ratios, for precautionary and settlement balances, or to reap returns in the case of remunerated reserves (Keister 2012). When faced with decreases in bank deposits and reserve balances when CBDC is introduced, commercial banks can respond by adjusting their demand for reserves in several ways. However, the precise magnitudes of these adjustments are difficult to determine without data (Malloy and others 2022). Some potential reactions include:

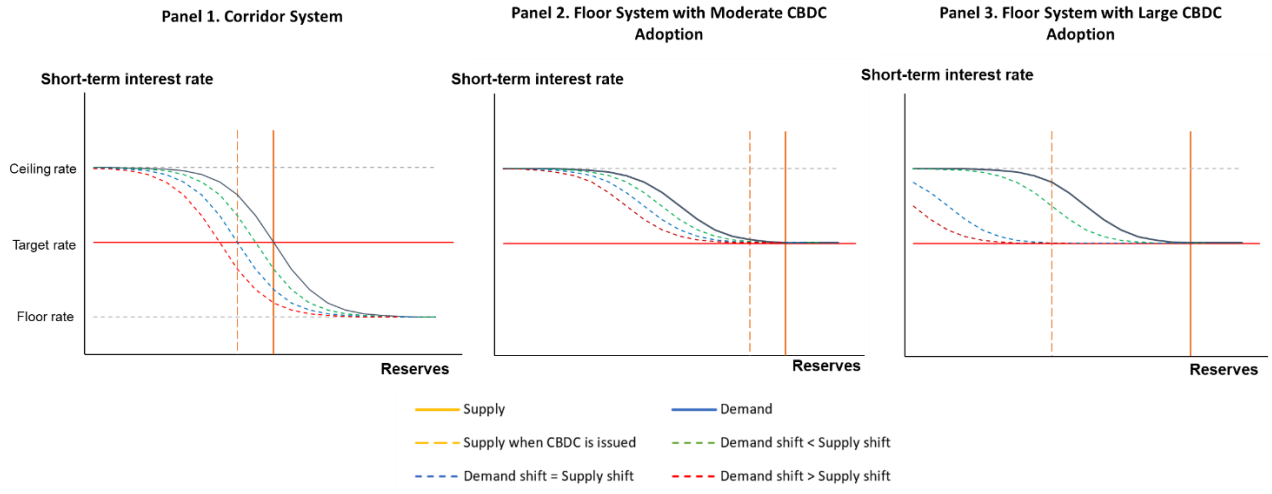
- With fewer reserves (the initial direct effect), the balance sheets of banks shrink, and the reserves-to-deposit ratio used to satisfy RRs may fall below the required or preferred level. While commercial banks would demand more reserves to maintain the ratio, the aggregated demand would be lower because of a lower deposit base.
- On the one hand, if retail payments activity shifts to CBDC, commercial banks' intraday reserve balances could become less volatile, and banks could demand fewer reserves for precautionary purposes (Malloy and others 2022). On the other hand, the ability for depositors to shift between deposits and CBDC very easily could lead to higher deposit volatility, leading banks to hold more reserves.
- Commercial banks could demand more reserves from the central bank to finance their operations (Brunnermeier and Niepelt 2019). Other options to counter funding pressures include attracting deposits by offering higher rates or turning to wholesale funding. If banks rely less on deposits, which are considered the most stable source of funding, they could demand more high-quality liquid assets such as reserves to satisfy regulatory ratios (Group of Central Banks 2021).

Taken together, short-term interest rates may experience some upward pressure in a corridor system, although unlikely in a floor system (where reserves are ample) unless substitution is significantly large.[9] In a corridor system where reserves are generally scarce, if the demand of reserves falls less than the supply, short-term interest rates would rise above the target level (Abad, Barrau, and Thomas 2023). However, if the demand for reserves falls by as much as the supply, then the short-term interest rates would not be affected. In a floor system in which reserves are ample, changes in the supply of reserves are unlikely to affect short-term interest rates unless the supply of reserves shrinks drastically to a level below the inflection point of the parsimonious floor while demand remains strong (Hauser 2022). Figure 4 illustrates these effects for the corridor and floor systems, as well as possible indirect effects related to demand curve adjustments.[10]

[9] When reserves are scarce in the banking system, the central bank can lend reserves in exchange for securities as collateral or buy securities in exchange for reserves (for example, repos and securities lending). Fewer securities in the market can have additional impacts on short-term rates.

[10] This note focuses on the short-term effects on reserves and the short-term market rates when CBDC is initially introduced. However, if, in the long term, CBDC adoption becomes significantly large while offering a floor, risk-free rate, it could possibly lower the overall funding cost by reducing interest rates in the financial markets (see Barrdear and Kumhof 2021). In addition, for more information about the demand for reserves modeling, please refer to Veyrune, Della Valle, and Guo (2018) and Chen, Kourentzes, and Veyrune (2023).

Figure 4. Different Degrees of the Shifts in Supply of and Demand for Reserves when CBDC Is Issued



Source: IMF staff calculations.
Note: The graphs illustrate different demand shifts. Specifically, they show three different cases: (1) a shift in demand that is smaller than the supply shift (green), (2) a shift in demand that is equal to the supply shift (blue), and (3) a shift in demand that is larger than the supply shift (red). In addition, the graphs in panel 2 assume a moderate CBDC adoption, while the graphs in panel 3 assume a large CBDC adoption and hence a large supply shift.

Finally, in Scenario 3 (CBDC substituting for reserves), short-term interest rates are unlikely to be significantly affected if CBDC is treated as equivalent to reserves. If CBDC is treated similarly to reserves in terms of regulatory treatment, remuneration, and access, then the total reserves would be the sum of the traditional reserves and wholesale CBDC. Thus, the effect on short-term rates should be muted to the extent that a decrease in reserves is offset by a corresponding increase in CBDC. Commercial banks thus hold an unchanged amount of central bank money in their wholesale accounts, and the central bank merely sees a change in the distribution of its liabilities, not a change in the levels. However, this result is dependent on the assumption that CBDC is largely treated the same as reserves.

Adapting Monetary Operations and CBDC Designs

In Scenario 1, and Scenario 2 in particular, the central bank would need to adapt its liquidity forecasting methodology. It is important to accurately forecast how CBDC would affect the level of reserve balances to calibrate monetary operations. As previously mentioned, CBDC demand is expected to be more volatile than CiC. Cambodia's Bakong system, although not a CBDC, shows such digital volatility effects (see Box 2).

As liquidity forecasting could be challenging, especially during the initial introduction of CBDC, several solutions may be implemented. A central bank targeting short-term interest rates in a corridor system may consider temporarily switching to targeting a fixed rate with full allotment until it can forecast reserves more accurately. As an alternative, the central bank could open more intra-day windows to allow for more fine-tuning operations. In addition, it could narrow the corridor between the ceiling and the floor rate, introduce a longer averaging period to satisfy RRs to limit the volatility of short-term interest rates, or provide liquidity at long maturity (Caccia, Tapking, and Vlassopoulous 2024). Overall, the central bank would need to monitor interest rate movements more actively.

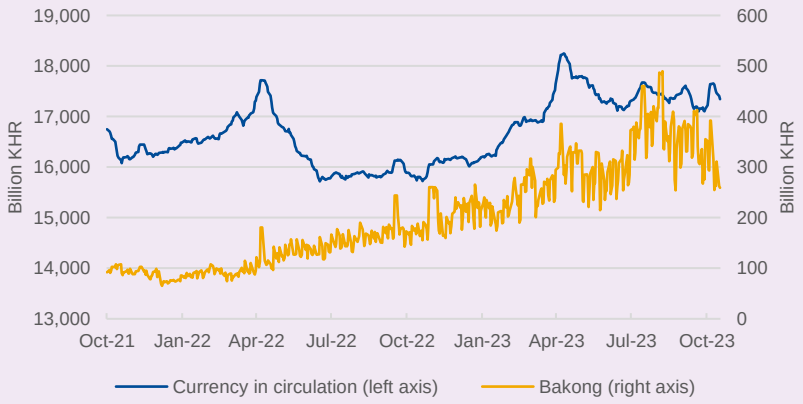
Box 2. Cambodia's Bakong System

In 2020, the National Bank of Cambodia (NBC) launched Bakong, a retail peer-to-peer digital payment system. Users' Bakong balances are part of the participating bank's liabilities. Although Bakong is not a CBDC and its adoption is still relatively small compared to currency in circulation (CiC), its digital nature and impact on liquidity can provide insights.

Reshuffling of banks' deposits at NBC takes place when a participating bank issues money to its users' Bakong wallets. When a participating bank issues money to its users' Bakong wallets, the bank needs to prefund its Bakong settlement account by transferring funds from its current account at the NBC. If demand for payments through Bakong were large, the participating banks would decrease their current account balances. The liquidity in the banking system would thus decrease the same way as if the demand for CiC increases. Therefore, Bakong must be accounted for as an additional autonomous factor when conducting liquidity forecast and the monetary operations should be calibrated accordingly.

Bakong operates on gross transactions, unlike cash which is on a netting basis, causing its transactions to be more volatile. Since the banks can only prefund their Bakong settlements accounts during the NBC business hours, this encourages banks to increase the accounts balances before weekends and national holidays, which is expected to make Bakong volumes more volatile. Being a relatively new system, Bakong's volatility was 36 times higher than that of CiC, with a daily average of 12.5 percent of Bakong compared to 0.3 percent for CiC (Figure 2.1), during October 2021–October 2023. As the system matures further, further insights and knowledge might be drawn.

Figure 2.1. Bakong and CiC Developments



Source: National Bank of Cambodia and IMF staff calculations.

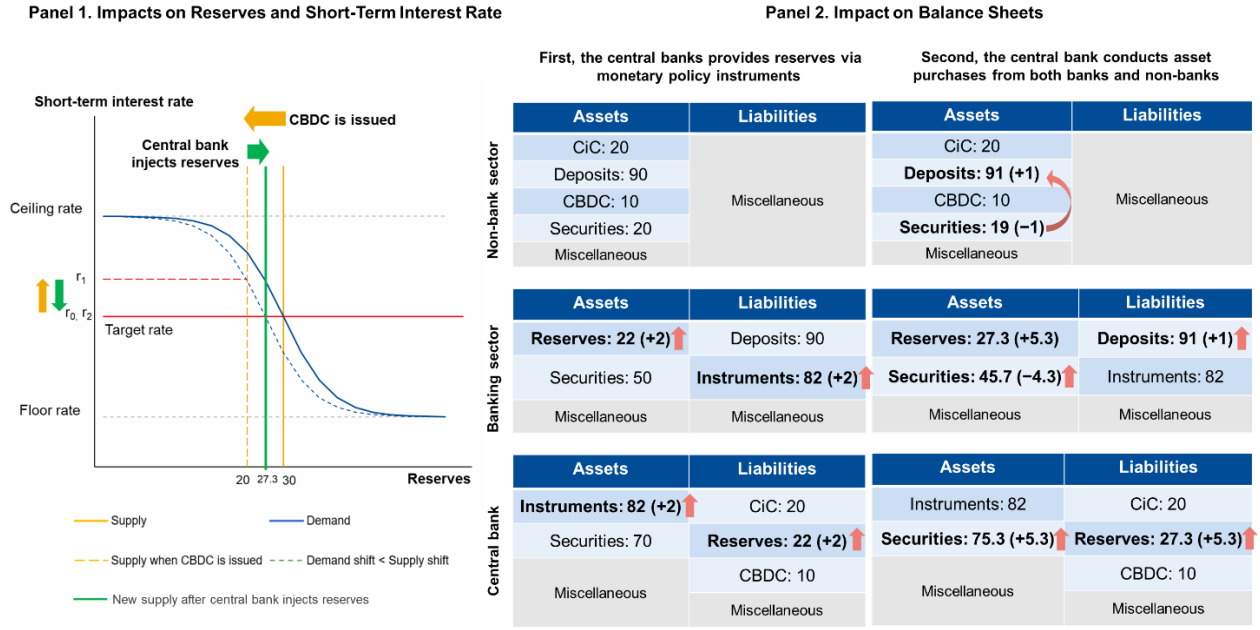
In Scenario 2, the central bank can provide additional reserves to the banking system to counter potential upward pressure on short-term interest rates. The central bank could inject reserves through OMOs, such as repurchase agreements with counterparties, or through SFs. Central banks engaged in liquidity-absorption operations, such as those required for sterilization, would instead need to taper their operations.[11]

If CBDC demand is large and persistent, the central bank may have to resort to asset purchases or long-term lending to the banking sector, resulting in a larger balance sheet of the central bank. The central bank could purchase government securities to permanently inject reserves into the system or provide liquidity through a monetary policy instrument with extended maturities. The approach would help ease potential reserve shortages arising from a significant and sustained substitution of bank deposits for CBDC. However, a larger central bank balance sheet could lead to increased exposure to interest rate, foreign exchange, and credit risks, potentially undermining the central bank's credibility and independence (He 2024). In countries with less developed securities markets and a limited availability of securities, central banks may be constrained by the supply of eligible assets. Large asset purchases could lead to rising bond prices and market distortions because of a liquidity crunch (Malloy and others 2022). Moreover, some central banks have institutional limits on the share of government securities that can be held (Abad, Barrau, and Thomas 2023). Also, if rapid outflows of bank deposits to CBDC result in a liquidity crunch, as seen during periods of financial market distress, the central bank must be prepared to provide a last resort lending to support banks.

Figure 5 shows a stylized example of the central bank's market interventions to offset upward pressure on short-term interest rates. It uses Scenario 2 in Figure 3 as a starting point, with leftward shifts of both supply of and demand for reserves and the reserve balance is at 20 units. In this case, the central bank will use both market instruments and asset purchases to supply reserves. First, the central bank responds by injecting reserves into the banking system through OMOs or SFs for two units, as shown in the first column of the balance sheets. Later, the central bank purchases securities from both bank and nonbanks. Assets can be purchased from the banking sector directly and paid for with central bank reserves or from the nonbanking sector and paid for with bank deposits. Since the deposits become 91 and to maintain the reserve requirement ratio at 0.3, the central bank provides additional reserves until the balance reaches 27.3 units, and the short-term rates go back to the target level, as shown in the Figure 5, panel 2. Figure 5, panel 1 shows how the short-term interest rates can be adjusted after the central bank's interventions.

[11] The central bank uses sterilization as a monetary tool to offset the impact of foreign exchange interventions on the domestic money supply. When the central bank buys or sells foreign currency to influence the exchange rate, it affects the supply of domestic currency. To control the money supply, the central bank carries out sterilization, typically by conducting open market operations. Some developing economies may use sterilization to manage capital inflows when faced with the risk of currency appreciation or inflation (Lee 1997).

Figure 5. Reserves and Balance Sheet Impacts when the Central Bank Provides Additional Reserves through Monetary Policy Instruments and Asset Purchases



Source: IMF staff calculations.
Note: CBDC = central bank digital currency; CiC = currency in circulation.

While Scenario 3 does not have a significant impact on the short-term rates, the central bank should ensure interoperability and facilitate exchanges between CBDC and reserves to prevent market price distortions and undesirable liquidity fragmentation. As mentioned, CBDC and reserves are assumed to exchange at par and on-demand, allowing banks with access to both systems to freely substitute without affecting the short-term interest rates. Nevertheless, banks would need to manage liquidity between the two systems, and the central bank should ensure the two systems are interoperable to facilitate seamless exchanges and avoid liquidity fragmentation.

In addition, to mitigate operational complexity, the central bank should treat wholesale CBDC as equivalent to reserves, especially concerning regulatory treatment, remuneration, and access. As previously mentioned, CBDC will likely possess a distinct use-value compared to reserves. Nevertheless, certain operational complexity could arise if CBDC is treated differently from reserves. The demand for reserves can become more erratic; for instance, it could spike before an RR averaging period ends or at the end of the day as banks seek to sweep funds into remunerated assets. Also, banks may end up holding insufficient CBDC to meet CBDC demand outside of the central bank's operation hours.[12] Moreover, they could incur additional costs associated with liquidity management from having to optimize holdings of CBDC versus reserves. For these reasons, some central banks experimenting with issuing wholesale CBDC for commercial banks have decided to treat CBDC equivalently to reserves, or to allow CBDC to be held only during intraday. For example, in Project Helvetia III, the Swiss National Bank treats

[12] A similar issue has arisen with cash, which has led some central banks which pay interest on reserves to resolve this by also paying interest on reserves on cash held in commercial banks' vaults.

wholesale CBDC as economically and legally equivalent to sight deposits on its balance sheet (Jordan 2024).[13] In Project Jura, wholesale CBDC existed only intraday and participating banks were required to convert their CBDC holdings into reserve balances in the real-time gross settlement systems by the end of day (BISIH, Bank of France, and Swiss National Bank 2021). Similar applicable lessons can be drawn from non-CBDC situations as in the case of the Bank of England omnibus accounts (see Box 3 for more details).

Box 3. The Bank of England Omnibus Accounts

In 2021, the Bank of England launched a new omnibus account model that enables a broader range of innovative payment system operators to access real-time gross settlement system. An omnibus account is defined as one where the funds of different entities are co-mingled in a single account offered to regulated payment system operators (Bank of England 2021). This will allow the operator to fund wholesale settlements on their platform with central bank money. The payment system operator will hold the omnibus account on behalf of their participants and is responsible for maintaining a one-to-one value of its omnibus accounts and the sum of participants' balances in its platform. While the balances held on the omnibus account overnight will be remunerated at the Bank Rate, the payment system operator holding the omnibus account must fully pass on the interest rate to participants in their system. As such, only entities that are participants in the Sterling Monetary Framework can hold an overnight entitlement.[1] By mandating this, the Bank ensures that the omnibus model has no impact on the transmission of monetary policy since funds in the omnibus account are treated at par with funds in the standard real-time gross settlement system accounts.

[1] Sterling Monetary Framework refers to the Bank of England's operational framework for implementing monetary policy in the sterling money markets. The participants of this framework include commercial banks, building societies, designated investment firms, and central counterparties. They have access to the reserve balances, which are remunerated at Bank Rate (Bank of England 2015).

Beyond the adaptation of the current monetary operation procedures, the central bank could alternatively consider altering the design of CBDC to attenuate the potential adverse operational impact from CBDC. However, CBDC design choices intended to mitigate adverse operational impacts could inadvertently undermine CBDC adoption. Central banks should carefully weigh these trade-offs when making strategic decisions on CBDC designs. Key CBDC design considerations include access, quantity limits, and remuneration; each is discussed separately as follows.

[13] In June 2024, the Swiss National Bank became the first central bank to carry out a monetary policy operation in a live production environment using distributed ledger technology by issuing CBDC and a Swiss National Bank Bill on the SIX digital exchange.

Access

Central banks could impose user criteria to access CBDC in order to control the likelihood of different scenarios**.** For example, by only allowing access to households (and potential intermediaries), CBDC transactions would be restricted to person-to-person payments, making Scenario 1 more likely. However, this more restricted access policy would limit use cases for CBDC, including as a potential settlement asset for tokenized assets. On the contrary, allowing for wider access to CBDC, by households, merchants, nonfinancial, and financial institutions alike, would have a greater impact on monetary operations, as the likelihood of Scenario 2 would increase. Access by foreigners could amplify any effects, potentially putting upward pressure on the exchange rate.

Quantity Limits

Another option to contain excessive substitution of deposits with CBDC is to limit the amount of CBDC that individuals and firms can hold. Some central banks have already adopted such policies. For example, Bahamas' Sand Dollar has a tiered wallet system, with Tier I wallets having a $500 holding limit and a $1,500 monthly transaction limit, whereas Tier II wallets have an $8,000 holding limit and $10,000 monthly transaction limit.[14] Nigeria's eNaira adopts a similar approach, including four types of wallets with different holding and daily funding and withdrawal limits.[15] Likewise, the Bank of England's Digital Pound consultation paper (Bank of England and HM Treasury 2023) proposes an individual holding limit of £10,000–£20,000, at least during the introductory period. Similarly, the European Central Bank has suggested that only €3,000–€4,000 of the digital euro could be held per person (Panetta 2022).[16] In addition, the digital euro will implement "waterfall" and "reverse waterfall" functionality to ensure compliance with the limits and facilitate smooth transactions between the digital euro and linked money accounts (see Bindseil, Cipollone, and Schaaf 2024 and Box 4). Similarly, the e-CNY "top up as you pay" function—automatic funding from bank accounts—ensures that users would not have strong incentives to maintain high balances in their e-CNY wallets.

Central banks could allow businesses to hold or transact larger quantities of CBDC**.** As companies have different sizes and engage in varying transaction volumes, the central bank may opt for a tiered limit system, as it would be challenging to impose a single limit for all types of corporations (Bank of England and HM Treasury 2023).[17]

[14] https://www.sanddollar.bs/individual

[15] https://enaira.gov.ng/for-individuals/

[16] The ECB has not made any final decision on the exact calibration of the holding limits and have stated that the setting of the holding limit will entail striking a balance between an optimal user experience and the need to maintain price stability and financial stability (see, ECB 2024a, ECB 2024b, and Box 4).

[17] Corporate use of the digital pound is still being explored.

Box 4. Digital Euro's Approach

The digital euro project is currently under a two-year preparation phase, starting from November 2023 to October 2025. The European Central Bank and national central banks aim to finalize the rulebook, select service providers, and carry out further experimentation including on technical aspects of the digital euro. This phase follows the investigation phase launched in 2021 to address key issues related to the design and distribution of the digital euro (ECB 2024a).

One of the key design features being experimented with is setting holding limits of the digital euro to ensure the stability of the financial system and of the monetary policy stance (even if the digital euro is not expected to be remunerated). Individuals and businesses can link their digital euro wallets with their private money accounts. The digital euro's design will include a "waterfall functionality," which allows for an automatic transfer of the digital euro to the linked private money accounts when the limit is reached, and a "reverse waterfall functionality," which allows for an automatic transfer from the linked accounts if the transaction value exceeds digital euro holdings. For merchants, the holding limit will be set to zero. Such mechanisms will help ensure financial stability and accessibility to central bank money, while maintaining financial conditions consistent with the monetary policy stance (ECB 2024b).

The European Central Bank is developing a framework to incorporate key factors for calibrating the appropriate holding limits and seeking feedback from stakeholders. The European Central Bank has launched a public dialogue and is collecting data to conduct the assessment. The precise holding limits will be determined based on this framework and defined nearer to the time of issuance (ECB 2024b).

Remuneration

Central banks may also consider remunerating CBDC to steer its demand relative to other payment and savings instruments. The digital nature of CBDC allows the central bank to tailor the setting of interest rates, including the possibility to charge negative rates. Kumhof and Noone (2018) propose that CBDC pays a variable rate lower than the policy rate to contain the substitution of bank deposits. While in the low to negative rate environment, Bindseil (2020) argues that offering a tiered remuneration, which offers a lower remuneration for CBDC held as a store of value (lower than bank deposits or other short-term financial assets), could also mitigate bank disintermediation and preserve the monetary policy stance. Meaning and others (2018) posit that the rate paid on reserves could be the primary rate of monetary policy while the rate paid on CBDC would be used to control demand for CBDC.

Such multiple interest rate offerings for central bank money have been observed. For example, the Federal Reserve's main implementation tools are interest on excess reserves and overnight reverse repurchase agreement program. Interest on excess reserves serves as an upper bound of the federal funds rate offered to financial institutions with reserve accounts, whereas overnight reverse repurchase agreement program serves as an effective floor for short-term interest rates (interest on excess reserves minus margin) offered through repurchase agreements with both banks and nonbanks such as money market funds and government-sponsored enterprises. The overnight reverse repurchase agreement

program also has allotment cap to mitigate financial stability risk.[18] The rates are technically adjusted relative to the target range, depending on conditions in the money market (Afonso and others 2022).

If remunerated, CBDC would become an additional policy instrument widely accessible by the public, potentially strengthening monetary policy transmission (Kahn, Singh, and Alwazir 2022). It could put pressure on banks to offer deposit rates more in line with the policy rate, and it could offer a savings instrument remunerated at (or close to) the policy rate to those without bank accounts. Improvements in monetary policy transmission will depend on competition in the banking sector. In a monopolistic banking sector, the introduction of CBDC could force a significant adjustment to bank deposit rates. In addition, changes in the CBDC interest rate could directly affect households' behavior. As a result, the short-term interbank interest rate may lose some of its importance as an operational target. However, the main channels of monetary policy are likely to remain in the bank lending or credit channels, as well as the exchange rate channel for more open economies. A CBDC can affect monetary policy transmission even if not remunerated since it would affect the economic environment (see also Das and others 2023 for more on CBDC and monetary policy considerations).

A central bank should consider the long-term viability and risks to its balance sheet if CBDC is remunerated. Transitioning from interest-free cash to interest-bearing CBDCs would ultimately affect the balance sheet, necessitating careful risk management by the central bank to ensure effective monetary policy, especially concerning the interest rate profiles of its assets and liabilities. In addition, seigniorage revenue could diminish (Kahn, Singh, and Alwazir 2022) (see Box 5 for further details).

Nevertheless, most central banks are considering zero remuneration in the case of a retail CBDC to encourage its main use as a payment instrument and to mitiage potential bank disintermediation. For example, to reduce competition with bank deposits, the e-CNY currently pays no interest (People's Bank of China 2021), similar to the retail CBDCs in the Bahamas, Nigeria, and Jamaica.[19] Likewise, the digital euro would not be remunerated if introduced (see Box 4).

Box 5. CBDC and Seigniorage

Central banks are typically the sole issuers of physical cash for their jurisdictions and earn seigniorage revenue. Seigniorage, which traditionally means the profit that a government makes from printing its own money, represents the difference between interest payable on the central bank asset holding (such as long-term government bonds) and the interest cost the central bank pays on central bank money (cash and reserves). Many central banks rely on seigniorage revenue to support their independence (Vergote and others 2010).

With declining demand for cash and increased demand for private digital forms of money, seigniorage earnings would be reduced. As such, CBDC may be seen as a help in preserving seigniorage revenue since a CBDC could ensure that some substitution of cash goes toward central bank digital money instead of commercial bank money.

However, the net impact of CBDCs on seigniorage is uncertain. It is influenced by factors such as remuneration rate, the size and composition of the central bank balance sheet, and *(continued)*

[18] The allotment cap is set at $160 billion per counterparty per day (Federal Reserve Bank of New York 2023).

[19] However, it is still possible that some central banks may choose the option of positive remuneration. In which case, understanding the effects on bank disintermediation would be crucial (see, for example, Chiu and others 2023; Infante and others 2023).

the cost of issuing money. On the one hand, remuneration can increase the demand for the CBDC and thus help raise seigniorage revenue; on the other hand, remuneration could imply lower seigniorage revenue if it raises the cost of issuing CBDC. As a digital product, CBDC has a lower marginal issuance cost than physical cash, which implies higher seigniorage when physical cash is substituted by CBDC, especially if CBDC is not remunerated.

Considerations for Foreign Exchange Rate and Monetary-Targeting Regimes

This section aims to provide further insights into the operational implications for exchange rate- and monetary-targeting regimes. Thus far, the analysis has focused primarily on the implications for inflation-targeting regime. However, monetary operations across monetary policy regimes are quite uniform, as presented in the earlier section (Disyatat 2008). Even central banks under exchange rate or monetary-targeting regimes also frequently monitor and manage short-term interest rates, with operations primarily focused on influencing the supply of reserves. However, certain additional subtleties are worth highlighting.

In an exchange rate-targeting regime, CBDC's availability to nonresidents could exert upward pressure on the domestic currency, induce more volatility of the exchange rate, and potentially lead to a more open capital account. CBDC could improve the liquidity or use-value of a domestic currency, thereby making it more attractive to hold relative to foreign currencies. In that case, all else equal, CBDC could lead to some currency appreciation, even if marginal. Nevertheless, quantifying this effect is difficult as few comparable examples exist. Similarly, CBDC could lead to greater exchange rate volatility if cross-border cross-currency transaction costs decreased substantially (He and others 2023). Another concern is how CBDC could undermine capital controls used to manage the capital account and the exchange rate. The IMF's CBDC Handbook chapter on capital flow management measures suggests that CBDC can either make a domestic currency more easily accessible and tradable by foreign residents, or it can allow for a more efficient and effective application of capital flow management measures if well implemented (He and others 2023). The ultimate effect will be country-specific, although concerned central banks implementing CBDC may need to stand ready to intervene more frequently, particularly through foreign exchange interventions, at least initially.

In a monetary-targeting regime, CBDC could alter the relationship between base money and broader money aggregates, and thus with inflation, thereby complicating monetary targeting. Monetary targeting typically assumes a stable relationship between the growth of base money or M0, and the growth rate of broader money aggregates. Under this system, the central bank controls monetary aggregates, which are considered the main determinants of inflation in the long term (Croce and Khan 2000). Historically, financial innovation has reduced transaction costs, resulting in instability of the relationships between monetary aggregates and other macroeconomic variables (Anderson, Bordo, and Duca 2016). Digitalization has led to a substitution of cash with digital payments, resulting in a decline in the CiC-to-GDP ratio and an increase in the money multiplier (broad money to M0) (see Box 6 for the example of M-Pesa in Kenya). Periods of rapid technological innovation, such as the introduction of automated teller machines and digital payments, have been accompanied by a structural shift and instability in money velocity (Lukonga 2023). CBDC could have similar effects. However, CBDC would be part of M0 and thus could counteract some of the effects of declining cash use.

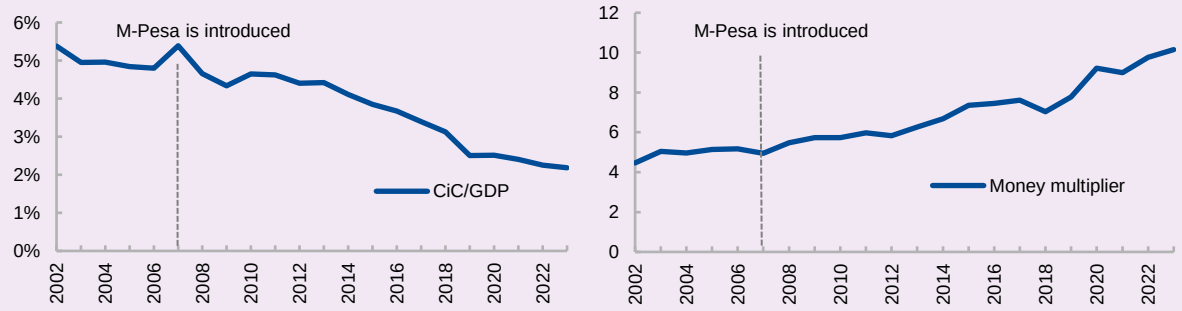
Box 6. Digitalization and Monetary Metrics: The Case of M-Pesa in Kenya

Many countries experiencing rapid digital payment adoption have observed a declining trend of currency in circulation (CiC) per GDP. In numerous cases, CiC has been a key driver of the growth in base money (M0). With the proliferation of digital payments, especially developing economies undergoing significant changes and rapid adoption, CiC per GDP is likely to continue its downward trend.

In 2007, Kenya launched M-Pesa, a mobile money transfer and financial services platform that allows users to deposit, withdraw, transfer money, and pay for goods and services using their mobile phones**.** Since the introduction, CiC per GDP has declined by half, while the money multiplier (the ratio of broad money or M2 to M0) has increased from below five to above ten (Figure 6.1). During 2001 to 2010, the average year-over-year percent change of the money multiplier is 2.78 percent, while the number increased to 5.08 percent during 2011 to 2020. The increasing money multiplier is because of a higher growth of M2 over M0.

Figure 6.1. Money Metrics in Kenya

(Percent and ratio, respectively)



Sources: International Financial Statistics and IMF staff calculations.

Note: CiC = currency in circulation.

Conclusions

Countries considering CBDCs often express interest in understanding the implications for monetary operations. After all, CBDC would become another liability of the central bank and could affect liquidity as households, firms, and banks potentially substitute CBDC for cash, bank deposits, and even central bank reserves.

On the one hand, this Fintech Note shows that CBDC may raise operational concerns. CBDC may affect central banks' ability to forecast liquidity, may draw market rates away from the policy target, and can complicate banks' liquidity management operations.

On the other hand, this note suggests that such adverse impacts may be attenuated by appropriately adapting the operations or CBDC design. This includes engaging in fine-tuning operations, providing more liquidity to the banking sector, and treating CBDC and reserves similar to the extent CBDC is available to commercial banks. However, such CBDC design choices could inadvertently affect other CBDC objectives, necessitating careful considerations of potential trade-offs.

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