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Synthetic Central Bank Digital Currencies and Systemic Liquidity Risks

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Abstract: The failure of major banks in 2023, such as Silicon Valley Bank (SVB), Signature Bank, First Republic Bank, and Credit Suisse, points to the continuing need for financial institutions to price liquidity risk properly and for financial systems to find alternative sources of liquidity in times of dire need. Central bank digital currencies (CBDCs), fiat-backed stablecoins (fsCOINs), and synthetic central bank digital currencies (sCBDCs) could offer improvements, but each comes with its own set of problems and conditions. Prior research reaches conflicting conclusions about the effect that each of these three financial assets has on systemic bank liquidity and fails to adequately address their net benefits relative to each other. This paper addresses these issues, including those connected to financial disintermediation, bank runs, outsourcing central bank activities, financial interoperability, cash equivalents, maturity transformation, required reserves, and changes in nations' monetary bases. After addressing the strengths and weaknesses of fsCOINs and CBDCs, we conclude that sCBDCs provide the most significant net liquidity benefits when risks and returns are considered.

Keywords: bank runs; cash equivalents; central bank digital currencies; disintermediation; interoperability; systemic liquidity; financial institution liquidity; monetary base; outsourcing; stablecoins; synthetic central bank digital currencies



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1. Introduction

“Liquidity risk” is the danger that a financial institution will be unable to borrow sufficient funds or convert enough assets to cash quickly and without substantial loss of value to meet its short-term expenditure obligations. Contagion occurs when the liquidity problems at one or more large financial institutions snowball, causing market asset prices to fall and volatility to rise, resulting in systemic (national or global) difficulties that decrease lending, reduce real GDP, and increase unemployment and financial disfunction. For banks, Mairafi et al. (2018) provide evidence of the significant effect liquidity has on bank performance and risk-taking, particularly in developed markets.

Systemic liquidity risks have been the bane of financial systems for centuries. The U.S. Federal Reserve's founding was mainly due to the Panic of 1907, when bank runs highlighted the need for a central source of liquidity during times of crisis. More recently, the Great Recession (2007–2009), precipitated by the subprime crisis, and the failure of Silicon Valley Bank (SVB), Signature Bank, First Republic Bank, and Credit Suisse in 2023, point to the continuing need for financial institutions to find ways to price liquidity risk correctly and for financial systems to find alternative sources of liquidity in times of dire need. Central bank digital currencies (CBDCs), fiat-backed stablecoins (fsCOINs), and synthetic central bank digital currencies (sCBDCs) could offer improvements, but each comes with its own set of problems and conditions.

The contribution of this work is twofold. First, it increases our understanding of how the introduction of synthetic CBDCs affects liquidity and risk at the individual financial institution and system-wide levels and how their introduction affects financial institutions'

deposit and loan costs. Second, it fills a gap in prior research by comparing the liquidity and systemic risks that accrue with different central-bank-supported and non-central-bank-supported stablecoins, namely CBDCs, sCBDCs, and fsCOINs. We conclude that sCBDCs provide the most significant net liquidity benefits when risks and returns are considered. The practical implication of this finding is that more attention needs to be paid to this alternative, both by academic research and by central banks around the world that are considering the development of a CBDC.

The remainder of this manuscript is organized as follows: Section 2 examines prior research regarding the liquidity risks of the major stable-valued forms of digital currency. Section 3 covers our research methodology. Section 4 presents our results, with subsections on fsCOINs, CBDCs, and sCBDCs, and Section 5 summarizes our conclusions.

2. Review of the Literature

The literature surrounding the liquidity risks of fsCOINs has focused on their similarity to money market funds (MMFs) and exchange-rate pegs. [Martino \(2022\)](#) draws attention to their procyclicality and maturity and liquidity transformation, concluding that fsCOINs present systemic liquidity risks similar to those of MMFs before European regulation and arguing that the European Union's Markets in Crypto Assets Regulation (MiCA) should favor market stability over investor protection and innovation. [MacDonald and Zhao \(2022\)](#) contend that fsCOINs' collateral chains and maturity and liquidity transformation cause destabilizing systemic risks to financial systems during periods of financial stress when flights to safety and flights to liquidity cause financial asset prices to plummet. [Adachi et al. \(2022\)](#) and [Kwon et al. \(2021\)](#) stress the need for reserve transparency, particularly as fsCOINs become more widely used, connections to legacy banking systems grow, and their current uses in decentralized finance (DeFi) activities, such as liquidity pools, increase. [Ahmed et al. \(2024\)](#) use a global games framework to analyze the effect that public disclosure and transparency of reserve quality and volatility have on an sCOIN's run risk. They conclude that when holders have relatively high (low) priors about reserve quality or transaction costs, greater (lower) public disclosure reduces (increases) sCOIN run risks. Furthermore, these digital assets appear to be resilient to mild changes in reserve values (i.e., quality) but highly vulnerable to significant shocks.

Using the liquidity coverage ratio (LCR) as their funding measure for five stablecoins (i.e., BUSD, DAI, USDC, USDP, and USDT), [Siddique et al. \(2023\)](#) found inconclusive evidence from 2019 to 2023 that higher pre-crisis LCRs improved a stablecoin's liquidity during financial crises. In this period, Terra Luna (May 2022), FTX (November 2022), Silicon Valley Bank (March 2023), and Signature Bank (March 2023) failed. Relationships varied by the types of crisis, stablecoin, and driver (e.g., exchange rate). Their conclusions point to the need for other forms of precautionary resiliency—perhaps involving regulation.

[Kim \(2022\)](#) focused on how cryptocurrency markets and traditional financial markets are linked via reserve-backed fsCOINs, for which growth has increased the demand for safe, short-term money market instruments. During the 2007–2008 financial crisis, as contagion spread from one private money market to another, questions of systemic liquidity risks arose. Kim concluded that the issuance of major fsCOINs, such as Tether and USD, caused significant increases in commercial paper issues and lagged decreases in the yields on commercial paper and Treasury bills.

[Bolt et al. \(2022\)](#) analyzed the design characteristics needed for fsCOINs and CBDCs to coexist with bank deposits and non-backed cryptocurrencies. They found that the optimal balance between trust and innovation for these public and private digital currencies required fsCOIN and CBDC convertibility and effective regulation.

The [G7 Working Group on Stablecoins \(2019\)](#) provides an overview of the possible strengths and weaknesses of fsCOINs, and the literature focusing on their liquidity poses concerns similar to those of CBDCs. For example, [Morgan \(2022\)](#) and [Bains et al. \(2022\)](#) argue that reserves held at commercial banks by fsCOIN issuers pose systemic risks if these

funds are mismanaged, poorly invested, or withdrawn in significant amounts, igniting security sales and rapid price decreases that result in widespread bank runs.

Because few CBDCs or sCBDCs exist, prior research regarding their impacts on systemic liquidity primarily consists of mathematical models and applications of economic theory rather than empirical research. Nevertheless, a relatively recent empirical study (Nguyen et al. 2023) concludes that advanced CBDC implementations reduce banks' core deposits, resulting in greater liquidity risk, as measured by the loan-to-deposit ratio.¹ The study used a dataset of 804 banks in 47 countries from 2010 through 2021. The primary independent variable, CBDC adoption, was scored on a scale from 0 to 4, representing no interest (0), research (1), proof-of-concept (2), pilot testing (3), and full adoption (4). A linear model was estimated, controlling for bank and macroeconomic variables. Notably, the authors did not control for non-CBDC-related variables that would significantly affect the loan-to-deposit ratio, such as the risks associated with changing macroeconomic conditions (e.g., the subprime crisis, Great Recession, and failure of significantly important banks, like Credit Suisse and SVB); central bank policies (e.g., adjustments in reserve requirement ratios); loan demand; and fluctuations in the public's relative preferences for cash, near-money deposits, and excess reserves, all of which would influence the money multiplier.

Although the coefficient of CBDC adoption was significant at the 1% level, the within- R^2 value of the four estimated models ranged from 0.03 to 0.07, indicating that very little of the variance was explained (Nguyen et al. 2023). This is not surprising, as there is little reason to believe that changes in CBDC adoption from no interest (0) to research (1) or from research to proof-of-concept (2) or even from proof-of-concept to pilot testing (3) would significantly impact bank liquidity in a country, as there would be almost no conversion from bank deposits to CBDCs and, therefore, no drain on the availability of bank reserves. Even in the Bahamas, one of the only places where full CBDC adoption has occurred, use has been minimal, with only 80,000 Sand Dollars in circulation as of the end of 2020 (Digital Euro Association 2023), the last year of the study. We are reminded that correlation does not imply causation.

Mancini-Griffoli et al. (2018) and BIS (2020) explore many of the pertinent concerns about structuring CBDCs. Jun and Yeo (2021) build a microeconomic banking model that analyzes the impact of account-type CBDCs² on bank loan supplies and bank failure risk. The model optimizes a bank's decisions about reserves, loan quantity, loan interest rates, and deposit interest rates. The authors conclude, "the ultimate impact on bank failure risk depends on the difference between the rates of return on successful businesses and the rates on loans." As loan market conditions become more favorable to borrowers, this difference becomes smaller, and bank failure risk increases. However, when the loan market is unfavorable, bank failure risk decreases and becomes insignificant. The authors note that risk failure relates to individual banks and is not systemic.

Kuehnlenz et al. (2023) argue that interest-earning CBDCs could threaten financial stability by accelerating the process of financial disintermediation from commercial banks to CBDCs, particularly for major currencies. They question if retail CBDCs, in particular, are the means to a more stable financial system, favoring instead putting limits on the amounts users can hold or transact. BIS (2018) explores the implications for designing and adopting a CBDC with or without interest and with or without quantitative CBDC use or holding limits.

Kumhof and Noone (2021) provide an opposing perspective, arguing that a well-designed CBDC, following four conservative design principles, eliminates the likelihood that it will increase the risk of bank runs. Among these principles are that the CBDC must pay an adjustable interest rate and that the convertibility of bank deposits to CBDCs at commercial banks is not guaranteed. Keister and Monnet (2022) go even further, observing that a CBDC removes the opacity of financial markets, allowing the central bank to observe the inflow and outflow of bank funds and thereby anticipate and mitigate, through prudent macroeconomic adjustments, the leadup to a financial crisis. Kim and Kwon (2023) build

a monetary equilibrium model that predicts that a sufficient increase in the quantity of CBDCs, not requiring reserve holdings, can enhance financial stability by increasing the credit supply and lowering nominal interest rates. [Andolfatto \(2021\)](#) finds that CBDCs pose no significant threats to bank lending activity and could encourage it via higher deposit rates, which reduce bank profits but encourage saving and greater financial inclusion.

[Bidder et al. \(2024\)](#) find CBDCs offer positive welfare effects if they are introduced slowly and become fixtures in household portfolios (i.e., “slow disintermediation”), but their potential to spark bank runs (i.e., “fast disintermediation”) offsets these prospective gains, resulting in decreased financial stability and net welfare losses. Turning these net losses into gains might be accomplished by slowing the disintermediation potential in times of distress by imposing holding limits or pegging CBDC remuneration to policy interest rates.

An empirical analysis by [Luu et al. \(2023\)](#) reinforces the conclusion that CBDCs promote financial stability by reducing leverage risk and asset risk. [Juks \(2018\)](#) analyzes the effects a Swedish e-krona would have on bank liquidity, financing sources, and funding costs, concluding that the potential conversion of bank withdrawals to CBDCs can be managed or partially counterbalanced by interest rate adjustments and greater reliance on longer-term financing. [Kim and Kwon \(2019\)](#), [Carapella and Flemming \(2020\)](#), and [Fernández-Villaverde et al. \(2021\)](#) conclude that CBDCs could cause liquidity problems owing to depositors’ withdrawals from commercial banks.

In contrast to the volume of research on fsCOINs and CBDCs, there has been a paucity of research on sCBDCs. [Adrian and Mancini-Griffoli \(2021\)](#), were among the first to analyze the pros and cons of sCBDCs as a form of digital money. Indeed, the BIS ([BIS 2020](#), p. 4) argued that a “‘Synthetic CBDC’ is not a CBDC” because, among other things, “central banks have public policy, rather than profit, objectives”, and “central banks can expand their balance sheets and create additional liabilities, at short notice, in response to underlying demand.” Nevertheless, several articles (e.g., [Juškaitė et al. 2019](#); [Whited et al. 2023](#)) have considered sCBDCs to be a form of CBDC.

In summary, the literature addressing the impacts of fsCOINs and CBDCs on bank liquidity and systemic risk is inconclusive. Furthermore, existing research fails to consider how a CBDC might act to offset an increasing use of fsCOINs, which bring their own liquidity risks to the market. Finally, research on liquidity risk and financial stability most often assumes that banks are disintermediated rather than forming partnerships with the central bank, allowing them to issue CBDCs on the central bank’s behalf, a product typically called a synthetic CBDC (sCBDC). This paper is motivated by the need to consider how these three somewhat substitutable forms of currency—fsCOINs, CBDCs, and sCBDCs—compare in their impacts on the liquidity risk and financial stability they bring to the market.

3. Method

Because of the very limited implementation of CBDCs and sCBDCs, the availability of data is insufficient for conducting a quantitative analysis. Owing to the intractability for building a model that realistically accounts for the competition among various forms of digital money, the behavior of central banks, the confounding factors of foreign exchange rates, interest rates, and consumer demand, we have instead relied on basic macroeconomic theory to answer these questions.

4. Results and Discussion

4.1. Stablecoins

A stablecoin is a digital currency issued by a private company or financial institution, with its value pegged to a fiat currency, basket of fiat currencies, or commodity, such as gold.³ Because this paper considers only stablecoins pegged to *fiat* currencies, such as the U.S. dollar or euro, we use “fsCOIN,” as our abbreviation for a “fiat-currency-denominated stablecoin”.

fsCOINs are not legal tender, and their issuers are independent of any central bank. Currently, they are used mainly to expedite trading, lending, and borrowing other digital assets (President's Working Group on Financial Markets et al. 2021). Speculators and investors also use them as collateral to leverage positions and to buy and sell digital assets in a distributed ledger environment without the need for fiat currencies and traditional financial institutions. Given their diminutive relative size, they are insignificant sources of demand for nations' goods and services. Therefore, they are not major causes of inflation or deflation. With proper reserves to back them and seamless operations, fsCOINs have the potential to serve as complements of nations' M2 money supplies.⁴ Furthermore, their issuance and use provide incremental testing grounds for innovative payment platforms and features, such as interoperability with other payment systems, user-friendliness, user-acceptance at the wholesale and retail levels, and an ability to comply with "Know Your Customer" (KYC), "Anti Money Laundering" (AML), and "Combating the Financing of Terrorism" (CFT) regulations.

Critical to an fsCOIN's value are its issuance and redemption rules. Issuance relates to controlling the number of fsCOINs in circulation to prevent over- or under-supply; redemption concerns the ability to satisfy holders' demands to convert them to their pegged currencies.⁵ Because an fsCOIN's value is determined by the forces of supply and demand, changes in demand (supply) must be met by an equivalent and offsetting change in supply (demand). Therefore, every fsCOIN has a risk-bearer who enjoys gains when demand rises and absorbs losses when it falls.

The main U.S.-dollar-backed fsCOINs are USD Coin (USDC), Binance USD (BUSD), Pax Dollar (USDP), and Geminin Dollar (GUSD). Among the significant non-U.S.-dollar-backed fsCOINs are Tether (USDT) and TrueUSD (TUSD). Multi-collateral Dai (DAI)⁶ and Liquidity USD (LUSD) are backed by cryptocurrencies (e.g., Bitcoin and Ether) and minted and burned by smart contracts. Algorithmic fsCOINs have no asset backing. Instead, smart contracts regulate their supplies and demands to ensure currency pegs are maintained. A popular algorithmic fsCOIN is Frax (FRAX).⁷ Finally, sUSD is an fsCOIN backed by the Synthetix Network Token (SNX), on which users stake SNX tokens as collateral to mint sUSDs. As a result, an sUSD's value is supported by the staked SNX tokens.

Table 1 shows the top ten fsCOINs' market capitalization on 16 January 2024. The top two had a combined value greater than \$120 billion, which exceeded by a considerable amount JPMorgan Prime Money Market Fund, which had roughly \$79 billion in assets (J.P. Morgan Asset Management 2024).

Table 1. Stablecoins by market cap and volume on 16 January 2024.

Stablecoin Name	Symbol	Price	Market Cap	Circulating Supply
Tether	USDT	\$1.000195	\$95.14 billion	\$95.12 billion
USD Coin	USDC	\$1.000300	\$25.44 billion	\$25.44 billion
Multi-Collateral Dai	DAI	\$0.999186	\$5.34 billion	\$5.35 billion
First Digital USD	FDUSD	\$1.001795	\$2.10 billion	\$2.09 billion
TrueUSD	TUSD	\$0.989888	\$1.89 billion	\$1.91 billion
Frax	FRAX	\$0.995967	\$646.84 million	\$649.46 million
Binance USD	BUSD	\$0.993907	\$412.23 million	\$414.76 million
Pax Dollar	USDP	\$1.001309	\$363.26 million	\$362.79 million
PayPal USD	PYUSD	\$0.998815	\$293.85 million	\$294.20 million
sUSD	sUSD	\$0.977720	\$220.45 million	\$225.47 million

Source: CoinCodex: Stablecoins by Market Cap and Volume, <https://coincodex.com/cryptocurrencies/sector/stablecoins/> (accessed on 16 January 2023).

4.1.1. Liquidity Concerns about fsCOINs

The safety and liquidity of an fsCOIN is a function of the quantity and quality of its collateral backing and the depth of its secondary markets (Hampel and Gyöngyörová 2021).⁸ The safest fsCOIN is fully collateralized by safe assets denominated in the pegged currency, which are (1) short-term, (2) highly liquid, and (3) readily convertible to known amounts of cash, with minimal risk of their values changing. These reserve assets include deposits at other financial institutions (e.g., commercial banks); Treasury bills; commercial paper; precious metals, such as gold; cryptocurrency deposits; and other “cash equivalents.”⁹ Nevertheless, even with 100% reserve backing, fsCOINs can lose value if issuers become insolvent or illiquid owing to:¹⁰

- Losses on equity-financed or borrowing-financed investments;
- Mismanagement of deposited funds that render fsCOIN holders unable to clear and liquidate them; and
- Theft, fraud, deceit, incompetence, poor curation, and programming mistakes, which are threats amplified by the general lack of fsCOIN regulation.

To ensure that fsCOIN issuers’ losses on equity-financed or debt-financed loans do not jeopardize an issuer’s solvency, the reserves backing fsCOIN liabilities could be segregated and put into custody accounts, so they are unencumbered by any potential claims (Adrian and Mancini-Griffoli 2021).¹¹

To moderate liquidity, credit, and counterparty risks, fsCOIN holders may be able to purchase deposit insurance (if available) or credit default swaps (CDS) on fsCOIN issuers, but these solutions only serve to shift these risks from fsCOIN holders to insurance companies and CDS counterparties.¹² In 2021, the U.S. President’s Working Group recommended legislation that would allow only financial institutions with insured deposits to issue, redeem, and maintain fsCOINs (President’s Working Group on Financial Markets et al. 2021).

Because fsCOINs’ risk–return profiles are comparable to those of regulated bank deposits and other highly liquid money market assets, “regulation equality” implies that fsCOIN issuers should abide by similar (or identical) rules as banks or MMFs (Anadu et al. 2023; Catalini and Shah 2021) for: (1) liquidity, (2) equity, (3) loan concentration, (4) operational quality,¹³ (5) consumer protection, (6) stress testing, and (7) regulations governing transaction monitoring (e.g., KYC and AML rules), reporting suspicious transactions, and combating the financing of terrorism (CFT) (Bains et al. 2022). Owing to fragmentation and the decentralized nature of fsCOINs, achieving these goals is likely to be difficult, if not impossible, unless broad regulatory powers can be brought to bear on issuers, cryptocurrency exchanges, custodians, governance bodies, wallet providers, network validators, client fund managers, and market makers.

At the macroeconomic level, it is not clear that a monetary system centered around one or more digital currency networks would provide the optimal amount of liquidity to maintain solid real GDP growth with low inflation and an adequate emergency liquidity-funding facility. These concerns are reinforced by the uncertainty that these networks would be interoperable (Brunnermeier et al. 2019).

4.1.2. Systemic Liquidity Concerns about fsCOINs

Because fsCOINs are uninsured and their convertibility is uncertain, they may not be universally accepted in exchange for goods, services, or other cryptocurrencies. Therefore, issuers may need incentives to induce customers to use them. Inducements could come from anonymity or opportunities for customers to transact payments and receipts outside the traditional financial system. They might also be in the form of better financial services or higher interest rates.

fsCOIN issuers are particularly susceptible to runs, regardless of whether the causes are well-founded in fact. Suspicions that the reserves backing an fsCOIN are insufficient, illiquid, or, in some other way, threatened could cause holders to convert them to safer assets, such as the currencies backing them, financial instruments denominated in safe

fiat currencies, or secure cryptocurrency-denominated deposits. To meet fsCOIN holders' demands during a run, issuers would be forced to convert their reserve assets to the pegged currency. Many of these reserves are held as uninsured bank deposits¹⁴ and, owing to their size, often exceed insurance limits, which makes them particularly susceptible to runs. Just as fsCOIN issuers would be forced to liquidate assets to meet fsCOIN holders' demands during a run, the banks and other financial institutions in which fsCOIN issuers hold their reserves would be forced to do the same, draining funds from the interbank market and further increasing the supply of financial assets, resulting in lower asset prices (Klages-Mundt et al. 2020; Morgan 2022).¹⁵

Runs on fsCOIN issuers would not directly deplete the financial system's liquidity because funds would be shuffled from one financial institution to another. Nevertheless, compression in asset prices could affect the solvency and liquidity of individual financial institutions, and rising interest rates could further reduce financial intermediaries' profits, resulting in loan contraction.

The run on Terra in May 2022 negatively impacted other algorithmic-backed and asset-backed fsCOINs, such as Tether. On the positive side, the run on Terra resulted in net inflows to safe fsCOINs, such as USDC (Anadu et al. 2023). Similarly, in March 2023, USDC (i.e., USD Coin) experienced significant outflows when holders learned of its uninsured deposits held at SVB. USDC was considered among the safest reserves of all the fsCOINs, consisting mainly of U.S. Treasury securities, bank deposits, and MMFs. Nevertheless, news that about eight percent of these assets were held as uninsured deposits at bankrupt SVB triggered capital flight from USDC, which ignited outflows from Dai and Frax,¹⁶ for which reserves included extensive holdings of USDC.

An interesting commonality between the 2022 run on Terra and the 2023 run on USDC was that capital fled from fsCOINs to other fsCOINs, not from fsCOINs to traditional money market investments, such as MMFs. Investors largely replaced relatively risky Terra and USDC with fsCOINs that were perceived as safer, such as Tether (USDT) (Anadu et al. 2023). An equally interesting difference between the Terra and USDC runs was that fsCOINs considered relatively safe before the run, such as USDC, became the relatively risky ones afterward, and relatively risky ones beforehand, such as USDT and TUSD, became the relatively safe ones.

4.2. Central Bank Digital Currencies

Central bank digital currencies (CBDCs) are issued and backed by nations' monetary authorities. They are denominated in sovereign money and equal in payment status to a country's monetary base (i.e., government-issued cash in circulation plus financial institutions' central bank deposits). CBDCs can be held in digital wallets as tokens or in accounts at central banks. They can also earn interest or not,¹⁷ as well as have targeted-use or universal-use designs (Keister and Sanches 2023). For nations for which currencies are not backed by precious metals, pegged to foreign currencies, or fixed to a foreign currency basket, CBDCs can be issued virtually without limit, implying their holders face no liquidity, counterparty, or credit risks. Unlike fsCOINs, CBDCs have no required asset backing. The quality of assets on central banks' balance sheets is at the discretion of monetary authorities. Central banks can become insolvent, but as long as they can continue creating monetary base, they can pay their fiat-currency-denominated obligations.

At the end of 2022, the Czech National Bank and central banks in Australia, Chile, Israel, Mexico, and Sweden were technically insolvent, reporting liability values above their assets. A case could be made that the U.S. Federal Reserve was also insolvent in 2022 and 2023, but it was rescued from this notoriety by an accounting tactic (Buiter 2023; Timiraos 2024). By contrast, fsCOINs are private liabilities. When they exceed asset values, issuers could face administration, liquidation, or receivership or file for bankruptcy protection.¹⁸

CBDCs are liabilities of monetary authorities and enter financial systems when central banks purchase financial assets, such as government securities, or lend to financial institutions. Their creation directly increases a nation's monetary base, and because they are

available on demand, central banks engage in maturity transformation when they acquire assets with maturities longer than those of their CBDC liabilities. In this way, CBDCs enable central banks to enjoy seigniorage rewards by issuing their own currencies. Table 2 shows the status of CBDCs worldwide as of 1 October 2023.

Table 2. Global status of CBDC developments on 1 October 2023.

Number of countries exploring CBDCs	130
Percentage of world GDP represented by 130 interested countries	98%
Number of countries in the advanced stage of exploration	64
Number of countries that have fully launched CBDCs	11
Source: Atlantic Council, Central Bank Digital Currency Tracker, https://www.atlanticcouncil.org/cbdctracker/ (accessed on 22 December 2023).	

CBDCs exist in two generic forms: wholesale and retail. These alternatives are addressed below.

4.2.1. Wholesale CBDCs

A wholesale CBDC is primarily used for transactions between financial institutions rather than retail transactions by individuals and small businesses. Wholesale CBDCs are offered either in one-tier or two-tier distribution forms. One-tier wholesale CBDCs are issued by central banks, mainly to large financial institutions with accounts at the central bank. Among the primary wholesale counterparties are banking institutions, primary dealers, counterparties to reverse repurchase agreements, investment managers of MMFs, government-sponsored enterprises, foreign official depositors, and international organizations, such as the International Monetary Fund, United Nations, and World Bank.

For two-tiered wholesale CBDCs, central banks:

- Manage the issuance, distribution, and regulation of CBDCs, including the quantity available and growth rate, and
- Provide authorized financial institutions, such as commercial banks, with access to CBDCs.

Thereafter, these financial institutions function as intermediaries between central banks and end-users, mainly significant-sized businesses and other large, wholesale users.

Financial intermediaries at this second level are responsible for distributing CBDCs, managing digital wallets, and providing other related services, thereby acting as a buffer between central banks and the public. If structured correctly, CBDCs can promote financial stability, inclusiveness, and safety (see [Kim and Kwon 2023](#); [Luu et al. 2023](#); [Auer et al. 2022](#)). They can also encourage digital payment innovation together with efficient and secure transactions.¹⁹

4.2.2. Retail CBDCs

Retail CBDCs are structured to address the needs of all customers, including small businesses and individuals whose transactions are massive in numbers but relatively small in average amounts. They can be structured so that payments and receipts are made directly via central banks or indirectly via wholesale re-issuers. In its direct form, individual and business owners of retail CBDCs hold deposits at the central bank, allowing for more effective monetary policies and the accumulation of direct customer transaction information ([Keister and Sanches 2023](#); [Auer et al. 2023](#); [Bordo and Levin 2017](#); [Barontini and Holden 2019](#)).

4.2.3. Liquidity Implications of CBDCs

CBDCs can significantly improve systemic liquidity in normal and stressful times, but their net benefits depend on whether:

- Fractional banking continues after CBDCs are created;
- They improve cross-border payment systems and the collection and curation of payment information;
- Technologies, payment platforms, and systems are made interoperable; and
- CBDCs are user-friendly and earn public trust.

Maintain Fractional Banking

If CBDCs were structured so that banks could hold them as fractional reserves against normal deposits, the private financial system could continue performing maturity transformation functions by borrowing CBDCs for short durations and lending domestic-currency-denominated checking accounts for longer ones.

Improve Cross-Border Payment Systems and the Collection and Curation of Payment Information

Many existing cross-border payment platforms are fragmented and costly, with incompatible messaging standards and complex compliance-processing rules. They offer limited operating hours, ambiguous fees, and long transaction chains and use outdated legacy platforms (World Bank 2021).²⁰ By contrast, CBDCs could be made available 24/7/365, clearing and settling transactions immediately. Their operational risks would be lower and efficiency (Wadsworth 2018), integration, and safety would be higher than those of traditional financial channels because central banks would have harmonized messaging standards and fewer intermediaries involved in each transaction. Their fee clarity would be enhanced using a single system with compatible wallet requirements (Auer et al. 2021; World Bank 2021). They could also reduce illicit behavior and moral hazard by increasing transparency and moderating asymmetric information.

CBDCs offer central banks opportunities to increase their information databases, providing real-time feedback and statistics on private financial systems and transactions. This information and direct access to it could enhance central banks' and governments' monetary and fiscal policies. Furthermore, they could allow central banks to implement monetary policies at a grassroots level, for example, by distributing stimulus payments and subsidies directly to individuals and businesses. A safe and stable CBDC could increase financial stability by providing strong competitors to private cryptocurrencies.

Technologies, Payment Platforms, and Interoperable Systems

Currently, the technology and consensus mechanisms that central banks and cryptocurrency issuers use can vary from currency to currency and from country to country,²¹ which is why CBDCs offer hope that strong international cooperation may be achieved to ensure interoperability with existing and forthcoming payment systems and financial infrastructures.

User-Friendliness and Earning Public Trust

Central banks, government agencies, and regulators determine CBDC rules, policies, directives, rights, responsibilities, and legal frameworks. Data privacy and consumer protection must be incorporated into the core CBDC design or become a programmed shell surrounding it. To prevent cyber-related threats, such as hacking, money laundering, terrorist financing, and counterfeiting, bulletproof security measures, such as multi-factor authentication and private/public key management, are essential to protect and engender users' trust.

Systemic Liquidity Concerns of Retail CBDCs

Because CBDCs are safer than checking accounts, private-sector financial institutions must offer customers incentives to diversify their portfolios with non-CBDC deposits. These incentives could be in the form of higher interest rates on deposited funds or improved financial services, such as those related to ease of use, clearing speeds, or consolidated

financial computer applications (Keister and Sanches 2023; Chiu and Davoodalhosseini 2023). Regardless, CBDC competition would raise banks' operational costs and reduce profit margins as the difference narrows between private sector uses and sources of funds. Lower profit margins could result in fewer loans, higher lending rates, and greater susceptibility to bank runs and financial institution failure.²²

If CBDCs did not exist, bank runs would result mainly in weak banks losing deposits and reserves to relatively healthy financial institutions and counterparties purchasing and selling financial securities. Regardless, the nation's monetary base would remain the same because bank runs would not drain the banking system of reserves. By contrast, a CBDC-based system would offer customers of private financial institutions opportunities to transfer deposits directly to the central bank, converting their relatively risky deposits to bulletproof CBDCs at the first sign of bank weakness. As a result, system-wide bank deposits and reserves would fall. Unless the central bank intervened to restore the lost liquidity, CBDC purchases could set off a system-wide demand for liquidity, causing interbank borrowing rates to rise and security prices to fall.

4.3. Synthetic Central Bank Digital Currencies

Synthetic central bank digital currencies (sCBDCs) are hybrid financial instruments with fsCOIN and CBDC attributes that potentially combine private sector innovation and efficiency with the trust and stability of central-bank-issued currencies.²³ They are the result of cooperative efforts by central banks and private enterprises that issue them, such as financial institutions, fintech companies, and decentralized protocols, perhaps using blockchain technologies. Like fsCOINs and CBDCs, sCBDCs' values are pegged 1:1 to a sovereign currency, such as the U.S. dollar or euro, but unlike fsCOINs, sCBDCs' liabilities are backed wholly by central bank reserves (i.e., one unit of central bank reserve deposits for each unit of sCBDC liability) and enjoy full guarantees of liquidity and safety by the central bank.²⁴ Because sCBDC issuers retain all their reserves at central banks, the adoption of sCBDCs does not cause nations to lose seigniorage revenues. The platforms and technologies used would be at the issuer's discretion, in coordination with the central bank.

4.3.1. Relative Benefits of sCBDCs for Central Banks

Adopting sCBDCs is a way for central banks to outsource costly and potentially problematic operational and administrative CBDC responsibilities, putting them squarely on the shoulders of private firms. Among these responsibilities are screening customers; offering wallets; updating computer systems; protecting customers and investors from fraud, misrepresentation, and scams; choosing appropriate technologies and settlement platform(s); managing customer information; supervising and monitoring sCBDC transactions; performing market surveillance of illicit activities (e.g., money laundering and terrorism financing); ensuring reimbursement in case of disputes; securing custody services; adopting platform standards; undertaking audits; ensuring transparency and privacy; and handling customer requests, complaints, and questions (Adrian and Mancini-Griffoli 2021). By outsourcing these activities to private vendors, central banks reduce the chances of cyberattacks on them, which could have systemic implications for the national and international financial systems and damage central banks' reputations.

By adopting sCBDCs, countries would share with private financial institutions, which have frontline connections to the market, responsibilities for identifying customer needs and developing new financial technologies and applications, such as novel cell phone and computer applications. Issuing sCBDCs with decentralized, open-source platforms could promote the development of smart contracts and financial innovations beyond those that central banks envision. Most important to the success of sCBDCs are trust and the networking benefits that come with scale. For this to happen, their acceptance as substitutes for cash (i.e., coins and bills) must be seamless. A government's willingness to accept sCBDCs in payment of taxes would improve their attractiveness.

An added benefit for having private firms address customer needs and develop modern technologies is that changes and modifications are likely to be incremental rather than discrete, offering opportunities for others to follow successful changes and shun those that are not. Central banks could try to do the same, but their efforts are more likely to result in changes that succeed or fail dramatically. Offering digital currencies on centralized ledgers opens the possibility of massive privacy losses due to cyberattacks.

Despite the private issuer's financial health, sCBDC holders enjoy full central bank backing. Nevertheless, these assurances of safety and liquidity could be strengthened by:

- Offering issuers access to central bank discount windows—particularly in times of systemic financial stress (Jun and Yeo 2021);
- Integrating sCBDCs into central bank clearing and settlement systems;
- Designing them to be interoperable with cross-border, sovereign payment, and other currency systems and platforms, such as using the mBridge Ledger (i.e., multicurrency bridge);²⁵
- Ensuring customer privacy by putting strict limits and protections on the distribution of financial information; and
- Monitoring and regulating sCBDC issuers' funding and lending activities to ensure that losses on their equity-financed or debt-financed loans do not jeopardize issuers' solvency.

For fairness and to encourage competition, the unique and privileged relationship that sCBDC issuers have with central banks implies a need to put them on an equal regulatory footing with financial institutions offering similar assets, such as banks, savings institutions, and MMFs. Two broad regulatory guidelines are:

- Financial institutions and financial instruments with equal expected risks and returns should be regulated equally, and
- Rules should be adaptive and flexible to accommodate changes in the future sCBDC landscape.

4.3.2. Systemic Liquidity Risks of sCBDCs

Among the weighty areas of concern regarding issuing, distributing, and using sCBDCs are increased operating costs for private financial institutions and the potential for significant changes in required reserves.

Increased Operating Costs for Private Financial Institutions

Because bank deposits carry higher liquidity, credit, and counterparty risks than sCBDCs, financial institutions that wish to issue deposits must offer incentives in the form of higher interest rates on deposited funds or improved financial services. The resulting increase in operational costs reduces private financial institutions' profit margins, which could decrease their loans and increase their vulnerability to bank runs. A slight improvement in bank profits might come from lower equity requirements because risk-weighted asset requirements on central bank deposits would equal zero (BIS 2017).

Funding costs and liquidity vulnerability might also increase for financial institutions that do not or cannot offer sCBDCs. As with CBDCs, if customers reduce their deposits at financial institutions not offering sCBDCs and deposit them at ones that do, the financial institutions with falling deposits and reserves would lose access to a relatively ample and inexpensive funding source.

Potential for Significant Changes in Required Reserves

The reserve requirement on checking deposits can vary significantly from country to country. In 2023, the worldwide average was about 7%.²⁶ Therefore, the movement of customers' funds from regular deposits to sCBDCs would cause an average increase in required reserves by 93%. If these transfers were made within the same banks, neither these banks nor the banking system would lose reserves or liquidity, but the financial institutions

in which the transfers were made would suffer meaningful increases in required reserves, forcing them to sell interest-earning assets, borrow from other banks or the central bank, and search for equity investors.

To get an idea of how the introduction of sCBDCs might affect bank and systemic liquidity, consider the SVB failure in 2023, when deposits worth \$40 billion were withdrawn on March 9, with more than 90% (i.e., about \$36 billion) uninsured. Assume that:

- SVB could offer customers either sCBDCs or regular deposits (e.g., checking, saving, or time deposits);
- The required reserve ratios on sCBDCs and deposit accounts were 100% and 0%, respectively;
- Customers could transfer funds between deposits and sCBDCs without limitation within licensed banks;
- Fully insured deposits could be withdrawn on demand and in full from SVB; and
- Gating restrictions on uninsured deposits limited weekly withdrawals to 10% of the total deposits, with no limits if adequate notice of 90 days was given.

Given these assumptions, insured deposits worth \$4 billion (i.e., 10% of the \$40 billion withdrawals) could have left SVB immediately, but the chances of this happening would have been dampened by SVB's insurance protection. The remaining \$36 billion in uninsured deposits could have been transferred, in total, to sCBDC accounts at SVB, causing SVB's total reserves to remain unchanged but required reserves to increase by \$36 billion. If depositors had chosen to place their funds in other banks, the most that could have been withdrawn from March 9 to March 16 would have been \$3.6 billion, with 10% of the remaining deposits available for withdrawal each subsequent week.

The important commonalities among all these alternatives are:

- The U.S. financial system would not lose any reserves;
- Reserve losses at SVB would be moderated by gating provisions and the opportunity to offer customers complete safety by transferring funds to central-bank-insured sCBDCs, and
- SVB would need to take appropriate action to increase its reserves and could do so by borrowing in the interbank market or from the central bank, selling financial assets, reducing loans, or seeking new equity infusions, but the timing and method chosen would be essentially a matter of discussion between SVB and the Federal Reserve. Massive and immediate sales of financial assets that could have contagion effects on the domestic and international financial systems could be avoided.

An added way that sCBDCs could stabilize the financial system is by requiring banks to pay uninsured deposits a lower interest rate than insured ones and for this differential to compensate the central bank. The differential's size could be related to a financial institution's relative risk based on factors such as liquidity ratios, equity as a percentage of risk-weighted assets, diversification, asset–liability maturity mismatch, and off-balance sheet exposures, with higher risks requiring a larger differential.²⁷ The reason for making central banks the beneficiary of this differential is that they are the ultimate sCBDC insurers or put-option sellers. If the differential for SVB had been 0.05%, it would have been required to pay the Federal Reserve \$180 million per year (i.e., 0.5% of \$36 billion) on its uninsured deposits.

5. Conclusions

CBDCs, fsCOINs, and sCBDCs enjoy a strong commonality in their one-to-one peg with a sovereign currency. At the same time, they can differ meaningfully in their platform architecture (e.g., open source versus proprietary technology), degree of ledger centralization, governance, transparency, redeemability, and interest return. Each of these financial instruments has different individual and systemic financial implications. Structured correctly, they can improve payment efficiency, lower financial costs, increase transaction throughput, reduce latency for large-volume transactions, and settle intra-border and cross-

border payment transactions in real time (i.e., immediately). They can also reduce the fees and inconvenience for handling, storing, and transporting cash. By increasing transparency, they hold the potential to reduce illicit activities, such as fraud, money laundering, and tax evasion. In combination with smart contracts, CBDCs, fsCOINs, and sCBDCs could stimulate innovations that improve the breadth, depth, quantity, and quality of financial transactions for existing customers and for individuals and businesses that are not currently served by traditional banking networks (i.e., the unbanked population).

The potential effects that CBDCs, fsCOINs, and sCBDCs have on systemic and individual financial institutions' liquidity have become focuses of interest, particularly among central banks, which are responsible for controlling inflation and making domestic and international payment systems as efficient, safe, inclusive, and user-friendly as possible. Each of these financial instruments has different individual and systemic financial implications:

- Runs on fsCOIN issuers pose significant liquidity threats to individual financial institutions, but because reserve losses of fsCOIN issuers are gained by other financial institutions, systemic liquidity is still maintained. Nevertheless, runs on large fsCOIN issuers could spread liquidity contagion to other financial institutions, resulting in systemic problems;
- CBDCs pose significant liquidity threats at both the systemic and financial institution levels. Because they offer complete protection from liquidity, counterparty, and credit risks, conversions of bank deposits to CBDCs are likely to occur at the hint of trouble, causing systemic reductions in bank reserves and the monetary base and triggering rising real interest rates due to massive sales of financial securities and increased demand for interbank loans;
- sCBDCs offer a way to moderate the adverse systemic and individual liquidity effects of significant runs on financial institutions. Allowing banks to offer deposits and sCBDCs reduces or eliminates the liquidity risks of massive withdrawals from any one financial institution or the financial system. sCBDCs are like liquidity put options, with central banks as the sellers, runs as the triggering "events", and time as the underlying.

The introduction and widespread use of fsCOINs, CBDCs, or sCBDCs by individuals, businesses, and governments could cause significant changes in the liquidity premiums on existing and new financial assets used for exchange and investment purposes. Properly constructed, an sCBDC offers the most hope to improve system-wide and financial-institution-specific liquidity shortages and surpluses, but its broader macroeconomic effects, when put into the context of changing international exchange rates, global capital flows, real versus nominal interest rates, inflation, and real GDP growth, remain ambiguous.

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Notes

- ¹ If the adoption of CBDCs increases systemic liquidity and credit risks, financial institutions should reduce loans relative to deposits, placing the remaining reserves in relatively safer interest-earning assets, such as central bank deposits, Treasury bills, and municipal bonds.
- ² The authors distinguish between account and token types of CBDCs, arguing that an account-type CBDC is a conventional demand deposit, whereas a token CBDC is more similar to cash or a gift voucher. Both types are liabilities of the central bank and, in our opinion, equal substitutes.

- 3 Banks are possible issuers of fsCOINs. In jurisdictions that prohibit bank-issued fsCOINs, special-purpose vehicles or subsidiaries might be a pathway to doing so.
- 4 In the United States, M2 includes currency in circulation (i.e., coins and cash outside banks), checkable deposits, small-denomination time deposits, and retail MMFs.
- 5 Some fsCOINs are not redeemable by their issuers but are still considered to be “cash equivalents” if they have liquid secondary markets, such as exchanges, on which they can be bought and sold.
- 6 To create DAI, holders lock up cryptocurrency collateral in smart contracts on the Ethereum blockchain. The computer algorithm overcollateralizes the outstanding DAI supply. Depreciation pressure is offset by the system automatically selling a portion of its reserves to maintain the fixed exchange rate. Smart contracts cannot exchange an fsCOIN for fiat currency because a contract cannot hold fiat currency. Instead, the agreement maintains an fsCOIN’s peg by allowing holders to exchange the fsCOIN for cryptocurrency of equal worth. Because the values of cryptocurrencies are highly volatile, smart contracts require overcollateralization.
- 7 FRAX has hybrid backing, using assets and a computer algorithm.
- 8 Lyons and Viswanath-Natraj (2023) find that stablecoin discounts during the COVID-19 crisis were largely due to liquidity effects and collateral concerns.
- 9 International Accounting Standards Board, 2017, paragraph 7: the definition of “cash equivalents” includes savings deposits, MMFs, and Treasury bills. In general, an asset is a “cash equivalent” if: Issuers provide holders with contractual rights to convert their holdings to an established amount of cash; Withdrawal notices of intent are not excessive; Withdrawal fees and restrictions on withdrawal amounts are reasonable; The risk of the fsCOIN’s value changing is insignificant; and They are held to manage short-term cash commitments rather than investments or other medium-to-long-term commitments.
- 10 Under Chapter 11 (reorganization), fsCOIN issuers could continue operations while restructuring and modifying their debts and business operations. IAS, Chapter 7 requires fsCOIN issuers to liquidate their assets.
- 11 Trusts are a potential answer, but more than the legal protections afforded to trusts may be needed to protect these funds from aggressive creditors. One solution to this potential problem is to segregate sCBDC reserves into one or more legally protected trusts. See Adrian and Mancini-Griffoli (2021).
- 12 In the United States, fsCOIN issuers that deposit reserves in insured depository institutions need “pass-through” deposit insurance for their customers to be protected, and this protection is limited to \$250,000 per customer. Without pass-through insurance, only the fsCOIN issuer would be covered up to a maximum of \$250,000.
- 13 Operational quality relates to an issuer’s information controls and processes, training, and resilience to external shocks that might affect service quantity and quality. Owing to the multiple levels of operations connected to fsCOINs and outsourced responsibilities, controlling operational risks may take time and effort. If the fsCOIN has open network access and consensus-based clearing and settlement, problems with quality control and accountability could be exacerbated.
- 14 Usually, the reserves of fsCOIN issuers at commercial banks exceed the insurance deposit limits, which are \$250,000 per customer per account in the United States.
- 15 Klages-Mundt et al. (2020) find that feedback effects from issuers deleveraging their balance sheets may have resulted in costs significantly higher than \$1 per stablecoin (e.g., Maker on Black Thursday in March 2020).
- 16 Frax is a partially algorithmic fsCOIN for which the value is set partly by reserves and an algorithm using Frax Shares, a flexible-exchange-rate cryptocurrency.
- 17 Keister and Sanches (2023) argue that varying interest rates on CBDCs could be a useful monetary tool.
- 18 Under Chapter 11 (reorganization), fsCOIN issuers could continue operations while restructuring and modifying their debts and business operations. Chapter 7 would require fsCOIN issuers to liquidate their assets.
- 19 Some studies (see Chiu and Davoodalhosseini 2023; Ahnert et al. 2023) have shown that CBDCs negatively affect financial stability. It should be noted that SWIFT, the primary cross-border payment system, was updated during the fall of 2023.
- 20 These technologies include blockchain and centralized digital ledger systems, and among the major consensus systems are Proof of Work and Proof of Stake.
- 21 Jun and Yeo (2021) find that system-wide loan supply and bank failure risks increase owing to banks lowering their excess liquidity reserves. Keister and Sanches (2023) find that a universal CBDC causing marginal increases in deposit rates could promote financial efficiency.
- 22 A fuller explanation of sCBDCs can be found in Adrian and Mancini-Griffoli (2021).
- 23 This 1:1 rule is similar to imposing a 100% reserve requirement on commercial banks, eliminating their ability to engage in fractional banking and maturity transformation.
- 24 The multi-CBDC platform mBridge is a joint project of the BIS Innovation Hub Hong Kong Centre, the Hong Kong Monetary Authority, the Bank of Thailand, the Digital Currency Institute of the People’s Bank of China, and the Central Bank of the United Arab Emirates (BIS Hub 2022).

- ²⁶ In 2023, the required reserve ratios worldwide varied from 0% (United States) to 73% (Venezuela), with the average equaling 7.4%. CEICA Data, Reserve Requirement Ratio, <https://www.ceicdata.com/en/indicator/reserve-requirement-ratio> (accessed on 24 December 2023).
- ²⁷ Since 2010, FDIC insurance premiums have been based on a bank's average consolidated total assets minus its average tangible equity. Therefore, this assessment has been based on total liabilities, not just insured ones. The specific rate charged is adjusted to reflect a bank's risk. The formula for small banks (i.e., those with less than \$10 billion in assets) is based on their CAMELS (capital adequacy, asset quality, management, earnings, liquidity, and sensitivity) ratings. Large banks' rates are based on individual scorecards. See FDIC, Assessment Rates and Methodology, <https://www.fdic.gov/resources/deposit-insurance-fund/dif-assessments.html> (accessed on 16 January 2024).

References

- Adachi, Mitsu, Pedro Bento Pereira Da Silva, Alexandra Born, Massimo Cappuccio, Stephanie Czák-Ludwig, Isabella Gschossmann, Georg Paula, Antonella Pellicani, Sarah-Maria Philipps, Mirjam Plooi, and et al. 2022. Stablecoins' role in crypto and beyond: Functions, risks and policy. *European Central Bank Macroeprudential Bulletin*. Available online: https://www.ecb.europa.eu/pub/financial-stability/macroeprudential-bulletin/html/ecb.mpbu202207_2~836f682ed7.en.html (accessed on 14 July 2023).
- Adrian, Tobias, and Tommaso Mancini-Griffoli. 2021. The rise of digital money. *Annual Review of Financial Economics* 13: 57–77. [CrossRef]
- Ahmed, Rashad, Iñaki Aldasoro, and Chanelle Duley. 2024. Public information and stablecoin runs. *BIS Working Papers* No. 1164. Available online: <https://www.bis.org/publ/work1164.pdf> (accessed on 31 January 2024).
- Ahnert, Toni, Peter Hoffmann, Agnese Leonello, and Davide Porcellacchia. 2023. Central Bank Digital Currency and Financial Stability (No. 18222). *CEPR Discussion Papers*. Available online: https://www.ecb.europa.eu/pub/conferences/shared/pdf/20231123_cepr_ecb/Ahnert_paper.it.pdf (accessed on 31 January 2024).
- Anadu, Kenechukwu, Pablo D. Azar, Marco Cipriani, Thomas M. Eisenbach, Catherine Huang, Mattia Landoni, Gabriele La Spada, Marco Macchiavelli, Antoine Malfroy-Camine, and J. Christina Wang. 2023. Runs and Flights to Safety: Are Stablecoins the New Money Market Funds? Federal Reserve Bank of Boston Working Paper No. 23-11. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4595172 (accessed on 31 January 2024).
- Andolfatto, David. 2021. Assessing the impact of central bank digital currency on private banks. *The Economic Journal* 131: 525–40. [CrossRef]
- Auer, Raphael, Giulio Cornelli, and Jon Frost. 2023. The Pandemic, Cash and Retail Payment Behaviour: Insights from the Future of Payments Database. CESifo Working Paper No. 10258. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4352370 (accessed on 31 January 2024).
- Auer, Raphael, Marc Farag, Ulf Lewrick, Lovrenc Orazem, and Markus Zoss. 2022. Banking in the Shadow of Bitcoin? The Institutional Adoption of Cryptocurrencies. Bank for International Settlements Working Paper No. 1013. Available online: <https://www.bis.org/publ/work1013.pdf> (accessed on 28 January 2024).
- Auer, Raphael, Philipp Haene, and Henry Holden. 2021. Multi-CBDC Arrangements and the Future of Cross-Border Payments. BIS papers. Bank for International Settlements, Number 115, July. Available online: <https://ideas.repec.org/b/bis/bisbps/115.html> (accessed on 28 January 2024).
- Bains, Parma, Arif Ismail, Fabiana Melo, and Nobuyasu Sugimoto. 2022. Regulating the Crypto Ecosystem: The Case of Stablecoins and Arrangements. International Monetary Fund. Available online: <https://www.imf.org/-/media/Files/Publications/FTN063/2022/English/FTNEA2022008.ashx> (accessed on 1 February 2024).
- Bank for International Settlements (BIS). 2017. Basel III: International Regulatory Framework for Banks. Available online: <https://www.bis.org/bcbs/basel3.htm> (accessed on 15 October 2023).
- Bank for International Settlements (BIS). 2018. Committee on Payments and Market Infrastructures Markets Committee. Central Bank Digital Currencies. Available online: <https://iepecdg.com.br/wp-content/uploads/2018/03/d174.pdf> (accessed on 30 January 2024).
- Bank for International Settlements (BIS). 2020. Central Bank Digital Currencies: Foundational Principles and Core Features, Report No. 1. Available online: <https://www.bis.org/publ/othp33.htm> (accessed on 27 December 2023).
- Barontini, Christian, and Henry Holden. 2019. Proceeding with Caution—A Survey on Central Bank Digital Currency. BIS Paper No. 101. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3331590 (accessed on 26 January 2024).
- Bidder, Rhys, Timothy Jackson, and Matthias Rottner. 2024. CBDC and Banks: Disintermediating Fast and Slow. Available online: https://matthias-rottner.github.io/Files/BJR_CBDC_Disintermediation.pdf (accessed on 31 January 2024).
- BIS Hub. 2022. Project mBridge: Connecting Economies through CBDC. Available online: https://www.bis.org/about/bisih/topics/cbdc/mcbdc_bridge.htm (accessed on 23 September 2023).
- Bolt, Wilko, Vera Lubbersen, and Peter Wierds. 2022. Getting the Balance Right: Crypto, Stablecoin and CBDC. De Nederlandsche Bank Working Paper No. 736. Available online: <https://ssrn.com/abstract=4014319> (accessed on 30 January 2024).
- Bordo, Michael D., and Andrew T. Levin. 2017. Central Bank Digital Currency and the Future of Monetary Policy. NBER Working Paper No. 23711. National Bureau of Economic Research. Available online: <https://www.nber.org/papers/w23711> (accessed on 30 January 2024).
- Brunnermeier, Markus K., Harold James, and Jean-Pierre Landau. 2019. *The Digitalization of Money* (No. w26300). Cambridge: National Bureau of Economic Research.

- Buiter, William H. 2023. Is the Fed's Negative Capital a Problem? Project Syndicate. Available online: <https://www.project-syndicate.org/commentary/federal-reserve-negative-capital-future-implications-by-willem-h-buiter-2023-09> (accessed on 1 February 2024).
- Carapella, Francesca, and Jean Flemming. 2020. Central Bank Digital Currency: A literature Review. FEDS Notes. Washington: Board of Governors of the Federal Reserve System. Available online: <https://www.federalreserve.gov/econres/notes/feds-notes/central-bank-digital-currency-a-literature-review-20201109.html> (accessed on 1 January 2024).
- Catalini, Christian, and Nihar Shah. 2021. Setting Standards for Stablecoin Reserves. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3970885 (accessed on 31 January 2024).
- Chiu, Jonathan, and Seyed Mohammadreza Davoodalhosseini. 2023. Central Bank Digital Currency and Banking: Macroeconomic Benefits of a Cash-like Design. *Management Science* 69: 6708–30. [CrossRef]
- Digital Euro Association. 2023. Lessons from the First Implemented CBDC: The Sand Dollar. Available online: <https://blog.digital-euro-association.de/lessons-from-the-sand-dollar> (accessed on 17 January 2024).
- Fernández-Villaverde, Jesús, Daniel Sanches, Linda Schilling, and Harald Uhlig. 2021. Central bank digital currency; Central banking for all? *Review of Economics Dynamics* 41: 225–42. [CrossRef]
- G7 Working Group on Stablecoins. 2019. *Investigating the Impact of Global Stablecoins*. d187. Basel: Bank for International Settlements Committee on Payments and Market Infrastructures, pp. 1–31.
- Hampl, Filip, and Lucie Gyöngyörová. 2021. Can fiat-backed stablecoins be considered cash or cash equivalents under international financial reporting standards rules? *Australian Accounting Review* 31: 233–55. [CrossRef]
- J.P. Morgan Asset Management. 2024. JPMorgan Prime Money Market Fund. Available online: <https://am.jpmorgan.com/us/en/asset-management/adv/products/jpmorgan-prime-money-market-fund-capital-4812a0367> (accessed on 17 January 2024).
- Juks, Reimo. 2018. When a central bank digital currency meets private money. *Sveriges Riksbank Economic Review* 3: 79–99.
- Jun, Jooyong, and Eunjung Yeo. 2021. Central bank digital currency, loan supply, and bank failure risk: A microeconomic approach. *Financial Innovation* 7: 1–22. [CrossRef] [PubMed]
- Juškaitė, Aistė, Sigita Šiaudinis, and Tomas Reichenbachas. 2019. CBDC—In a Whirlpool of Discussion. Lietuvos Bankas Eurosystema, Occasional Paper Series No. 29. Available online: <https://etalpykla.lituanistika.lt/object/LT-LDB-0001:B.03~2019~1604071876146/> (accessed on 30 January 2024).
- Keister, Todd, and Cyril Monnet. 2022. Central bank digital currency: Stability and information. *Journal of Economic Dynamics and Control* 142: 104501. [CrossRef]
- Keister, Todd, and Daniel Sanches. 2023. Should central banks issue digital currency? *The Review of Economic Studies* 90: 404–31. [CrossRef]
- Kim, Sang Rae. 2022. How the Cryptocurrency Market Is Connected to the Financial Market. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4106815 (accessed on 29 January 2024).
- Kim, Young Sik, and Ohik Kwon. 2019. Central Bank Digital Currency and Financial Stability. Bank of Korea WP 2019-6. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3330914 (accessed on 30 January 2024).
- Kim, Young Sik, and Ohik Kwon. 2023. Central bank digital currency, credit supply, and financial stability. *Journal of Money, Credit and Banking* 55: 297–321. [CrossRef]
- Klages-Mundt, Arian, Dominik Harz, Lewis Gudgeon, Jun-You Liu, and Andreea Minca. 2020. Stablecoins 2.0: Economic Foundations and Risk-Based Models. Paper presented at the 2nd ACM Conference on Advances in Financial Technologies, New York, NY, USA, October 21–23; pp. 59–79. Available online: <https://dl.acm.org/doi/abs/10.1145/3419614.3423261> (accessed on 29 January 2024).
- Kuehnlenz, Sophia, Bianca Orsi, and Annina Kaltenbrunner. 2023. Central bank digital currencies and the international payment system: The demise of the U.S. dollar. *Research in International Business and Finance* 64: 101834. [CrossRef]
- Kumhof, M., and C. Noone. 2021. Central bank digital currencies—Design principles for financial stability. *Economic Analysis and Policy* 71: 553–72. [CrossRef]
- Kwon, Y., J. Kim, Y. Kim, and D. Song. 2021. The Trilemma of Stablecoin. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3917430 (accessed on 31 January 2024).
- Luu, Hiep Ngoc, Canh Phuc Nguyen, and Muhammad Ali Nasir. 2023. Implications of central bank digital currency for financial stability: Evidence from the global banking sector. *Journal of International Financial Markets, Institutions and Money* 89: 101864. [CrossRef]
- Lyons, Richard K., and Ganesh Viswanath-Natraj. 2023. What keeps stablecoins stable? *Journal of International Money and Finance* 131: 102777. [CrossRef]
- MacDonald, Cameron, and Laura Zhao. 2022. Stablecoins and Their Risks to Financial Stability. *Bank of Canada Staff Discussion Paper/Document D'analyse du Personnel—2022-20*. Available online: <https://www.bankofcanada.ca/2022/11/staff-discussion-paper-2022-20/> (accessed on 28 January 2024).
- Mairafi, Salihu Liman, Sallahuddin Hassan, and Shamsul Bahrain Mohamed-Arshad. 2018. Systematic review of literature on effect of liquidity on bank. *Academy of Accounting and Financial Studies Journal* 22: 1–7.
- Mancini-Griffoli, Tommaso, Maria Soledad Martinez Peria, Itai Agur, Anil Ari, John Kiff, Adina Popescu, and Celine Rochon. 2018. Casting light on central bank digital currency. In *IMF Staff Discussion Note*. Washington, DC: International Monetary Fund.
- Martino, Edoardo. D. 2022. Regulating Stablecoins as Private Money between Liquidity and Safety. The Case of the EU 'Market in Crypto Asset' (MiCA) Regulation. Amsterdam Law School Research Paper No. 2022-27, Amsterdam Center for Law & Economics Working Paper No. 2022-07. Available online: <https://ssrn.com/abstract=4203885> (accessed on 28 January 2024).

- Morgan, Jamie. 2022. Systemic stablecoin and the defensive case for central bank digital currency: A critique of the Bank of England's framing. *Research in International Business and Finance* 62: 101716. [CrossRef]
- Nguyen, Dinh Trung, Minh Ngoc Nguyen, and Kim Thanh Duong. 2023. The impact of CBDC adoption on bank liquidity risk: Evidence from the global banking sector. *Applied Economics Letters*, 1–6. [CrossRef]
- President's Working Group on Financial Markets, the Federal Deposit Insurance Corporation, and the Office of the Comptroller of the Currency. 2021. Report on Stablecoins. Available online: https://home.treasury.gov/system/files/136/StableCoinReport_Nov1_508.pdf (accessed on 27 August 2023).
- Siddique, Akhtar R., Valerio Poti, Akanksha Jalan, and Roman Matkovskyy. 2023. Stablecoins: Funding and Market Liquidity. Available online: <https://ssrn.com/abstract=4562256> (accessed on 28 January 2024).
- Timiraos, Nick. 2024. Fed Posts Largest-Ever Annual Operating Loss. The Wall Street Journal. Available online: https://www.wsj.com/economy/central-banking/fed-posts-largest-ever-annual-operating-loss-6e249a39?mod=Searchresults_pos1&page=1 (accessed on 16 January 2024).
- Wadsworth, Amber. 2018. The pros and cons of issuing a central bank digital currency. *Reserve Bank of New Zealand Bulletin* 81: 1–21. Available online: <https://www.rbnz.govt.nz/-/media/4ee8fb7526804ed2924ad2d4c108fe3a.ashx> (accessed on 26 December 2023).
- Whited, Toni M., Yufeng Wu, and Kairong Xiao. 2023. Will Central Bank Digital Currency Disintermediate Banks? Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4112644 (accessed on 31 January 2024).
- World Bank. 2021. Central Bank Digital Currencies for Cross-Border Payments: A Review of Current Experiments and Ideas. World Bank Group Library: Books. Available online: <https://elibrary.worldbank.org/doi/abs/10.1596/36764> (accessed on 25 January 2024).

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