

A Review on the Implementation of Retail Central Bank Digital Currency (CBDC)

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ABSTRACT

This paper reviews academic research and policy reports on the design and implementation of general-purpose retail central bank digital currencies (CBDCs). It examines how differences in technical architecture and legal governance shape three contested outcomes: financial privacy, monetary-policy transmission, and the exercise of state power through digital payment systems. While critical literature warns that centralized digital ledgers could compromise financial privacy, create behavioral distortions near the Zero Lower Bound (ZLB), and enable state overreach, counter-arguments highlight structural mechanisms that mitigate these risks. Specifically, privacy-preserving architectures—such as "managed anonymity" piloted in China's e-CNY—demonstrate that semi-privacy can be secured for retail users. On the monetary front, retail CBDCs offer enhanced policy effectiveness through reduced transaction costs, broadened financial accessibility for underbanked populations, and precision fiscal delivery like targeted spending and stipends. Regarding state surveillance, the non-uniqueness argument suggests that existing commercial electronic payment rails already permit legal oversight and account interventions; thus, a CBDC transition streamlines administrative execution rather than introducing a novel violation of state-private boundaries, provided robust legal frameworks are implanted. Finally, this review explicitly focuses on retail CBDCs and acknowledges its heavy reliance on theoretical literature, as limited real-world empirical data from fully operational retail CBDCs is currently available.

1. INTRODUCTION

The past decade has seen an explosion of interest in digital assets in general and central bank digital currencies (CBDCs) in particular. CBDCs are frequently praised for the unique efficiency and security they provide when compared to existing forms of digital currencies and transaction media (Bindseil, 2020). While most central banks (117 out of 146) (Chhangani, 2026) are enthusiastically investigating and researching CBDCs, hoping they will serve as a primary, or even dominant, form of online currency, a growing counter-literature warns of the systemic socio-economic risks of this transition. These concerns become particularly acute if the evolution culminates in the elimination of physical cash and a complete transition toward digital state sovereignty.

Existing research on retail CBDCs is divided across several specialized debates. Technical studies examine ledger architecture(Hu et al., 2026), identity systems(SANGWA, 2025), and privacy-enhancing technologies(Nijse, 2026); economic studies consider payment efficiency(Mu, 2022), financial intermediation, and monetary-policy transmission(Yang, 2022); and legal and political scholarship focuses on surveillance, programmability, and limits on state authority(Jain, 2026). These bodies of literature are often evaluated separately, even though their conclusions depend on overlapping design choices. For example, a privacy-preserving architecture may reduce transaction visibility but complicate regulatory compliance, while a more direct policy-transmission mechanism may improve administrative efficiency but also increase concerns about user choice and institutional power.

Against this background, this review focuses on general-purpose retail CBDCs and excludes wholesale CBDCs used primarily for interbank clearing and institutional settlement. It does not assume that retail CBDCs will necessarily replace physical cash; instead, cash coexistence is treated as one of the design conditions that may shape their economic and political effects. The review addresses three questions: (1) under what technical and legal conditions can a retail CBDC preserve meaningful payment privacy; (2) how do remuneration, holding limits, intermediation, and cash availability affect its monetary-policy implications; and (3) when might faster and more centralized digital enforcement create civil-liberties risks beyond those already present in commercial payment systems?

The review asks which technical and institutional conditions make each claimed benefit or risk more plausible, including data-access arrangements, remuneration, holding limits, cash coexistence, programmability, and legal oversight. Its contribution is therefore a conditional synthesis of existing evidence, rather than the presentation of new empirical findings or the assumption that all retail CBDCs will follow a single model.

2. METHODOLOGY

To conduct a comprehensive review of this emerging topic, a structured search and discovery process was employed. Literature was initially retrieved from Google Scholar and JSTOR using targeted keyword combinations, including "retail CBDC," "Central Bank Digital Currency," "Zero Lower Bound," "managed anonymity," "e-CNY," "programmable money," "financial inclusion," "financial privacy," and "debanking." To complement these initial outputs and capture interconnected academic debates, a "snowball sampling" methodology (reference chasing) was applied, systematically tracking citations forward and backward across foundational articles, legal analyses, and central bank working papers—specifically those from the Bank for International Settlements, the European Central Bank, and the Federal Reserve. Selection criteria prioritized post-2020, post-Covid research, since the Covid-pandemic has encouraged wide adoption of online payment and digital assets, changing the public perception largely. This paper also focuses specifically on retail payment architectures, behavioral economics, and legal frameworks governing state authority.

3. PRIVACY

3.1 Traditional Privacy Baselines and Regulatory Evolution

Historically, mainstream monetary instruments preserved a high degree of transactional anonymity (ECB, 2019). In the past, currencies backed up by physical commodities, such as gold or silver, were inherently untraceable. When societies transitioned into fiat systems backed by government credibility, the structural friction within the financial system retained currency anonymity as a buffer between governments and individuals.

The preservation of financial privacy benefits consumers by protecting personal identities and ensuring fair pricing and equal access to goods and services. Concurrently, it is also recognized as a legal obligation for financial institutions under frameworks like the Financial Modernization Act of 1999.

However, existing legal frameworks, including anti-money laundering (AML) and combating the financing of terrorism (CFT) policies, remain structurally intact. Theoretical and statistical evidence indicates that effective AML policies successfully reduce corruption, bribery, and environmental crimes (Andiojaya, 2025). The baseline mechanics of these frameworks traditionally rely on five pillars: 1. Customer Identification Programs; 2. Customer Due Diligence; 3. Comprehensive recordkeeping; 4. Suspicious Activity Reporting; 5. Sanctions screening (Aidoo, 2025).

Currently, the financial system is undergoing a transition from delayed, reactive AML security checks toward real-time AML verification. By incorporating machine learning and artificial intelligence, institutions aim to prevent unlawful transactions proactively rather than retroactively (Shen, 2025). However, as long as financial data is collected, consumers remain concerned about their privacy.

Empirical data suggests that these stringent regulatory requirements fail to align with the privacy expectations of the public. According to a study by the CFA Institute, 57% of respondents in emerging markets and 64% in developed markets cite data privacy as their top concern regarding wide CBDC adoption (CFA, 2023). Critical legal and economic scholars argue that the implementation of a retail CBDC structurally alters the traditional privacy paradigm. Because CBDC architectures rely on centralized ledgers or monitored distributed ledger technology, the issuing central bank gains direct or indirect access to micro-transaction metadata. Furthermore, under current international regulatory baselines, users must undergo comprehensive Know-Your-Customer (KYC) identity verification to operate within the ecosystem. Consequently, researchers like Nijssse (2026) observe a systemic divergence between the "design phase" promises of privacy and the actual "launch versions" of CBDCs, where privacy protections are frequently attenuated to accommodate rigid regulatory demands.

3.2 Managed Anonymity and Semi-Privacy Technical Safeguards

Conversely, proponents and technical architects emphasize that privacy in a digital environment is not an all-or-nothing proposition, but a spectrum configurable through system design. Various strategies of privacy-ensuring mechanisms have been developed specifically to protect individual anonymity while fulfilling statutory compliance

Some CBDC designs attempt to provide a compromising solution by inventing "payer anonymity" (BIS, 2023), where commercial banks serve as the sole customer-facing service provider. While commercial banks perform "Know-Your-Customer" identity verification and necessary security checks, neither party in a retail transaction learns the private identity of their counterparty. Recent projects on privacy enhancing technologies provide developers with a prototype of how CBDCs can preserve payer anonymity while adhering to anti-money laundering policies, though such technologies are mostly in testing phases. (Rakesh, etc. 2025)

Real-world implementation models demonstrate that semi-privacy is practically achievable. In China's e-CNY framework, the central bank operates on the principle of "*anonymity for small value, traceability for high value*" (PBoC, 2021). Low-tier digital wallets can be opened using only a cell phone number without full bank account disclosure, granting everyday consumers transactional anonymity for routine daily spending. Only when transaction thresholds exceed designated limits are higher-level identity verifications triggered for AML compliance. In fact, the adoption of e-CNY in China has proven the public's acceptance of CBDC with its managed privacy: a total of 230 million personal wallets have been opened through the e-CNY app, and 18.84 million institutions established digital wallets. (Zhang, 2026) The wide adoption of e-CNY could be viewed as an example of semi-privacy successfully mitigating privacy concerns and the need for financial monitoring.

Another strategy addressing the issue relies more on advanced cryptographic designs. CBDCs could structurally include zero-knowledge proofs (ZKPs) and blind signatures that had been developed via blockchain for crypto-currencies. An empirical study demonstrated the promising outlook of ZKP technology in protecting payer identity by studying the reliability and scalability of various ZKP tools (Shashidhara R, 2024). This technology, if utilized in CBDC designs, may enable central banks to verify transaction validity and prevent double-spending without revealing the underlying transaction metadata or personal identity of the sender to the central ledger.

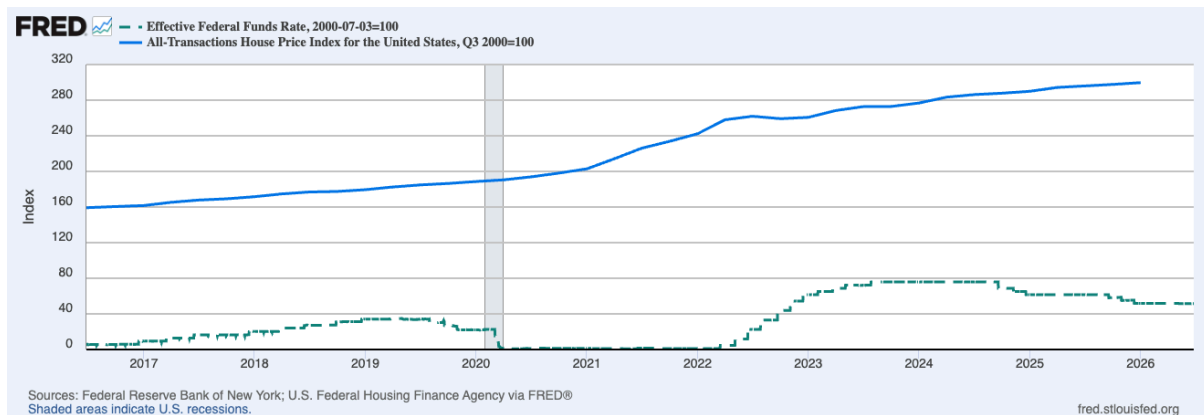
4. MONETARY POLICY BEHAVIOR

4.1 Unconventional Monetary Policies, ZLB, and Asset Market Distortions

In standard macroeconomic theory, the Zero Lower Bound (ZLB) represents a significant constraint on conventional monetary policy. When economic downturns require real interest rates to fall below zero,

central banks are historically limited by the existence of physical currency, which offers a guaranteed 0% nominal return. While traditional models treat the downward trajectory of interest rates as a linear mathematical continuum, empirical observations from recent crisis eras suggest that approaching or breaching the ZLB can induce severe structural distortions in asset markets.

Monetary interventions, such as those observed during the Covid-19 pandemic where the Federal Reserve reduced the federal funds rate to a range of 0% to 0.25%, demonstrate a potential decoupling between financial markets and real economic indicators (Milstein, 2024). Rather than serving purely as a harbinger of real economic recovery, drastically lowered interest rates (1.5%, which is lower than the rate of change during the Great Depression) can trigger a rapid re-pricing of risk assets. Interest rates are seen as the price of loans or the opportunity cost for investments in asset markets. With significantly lowered or negative interest rates, professional investors are more willing and enabled to invest in larger quantities of real estate. Specifically, institutional investors constitute 30% in Western markets, 40% in Indian markets, and 80% in Chinese markets' trading volumes (Spear, 2025; EconoFact). The lowered rates are coupled with rising asset prices, shown in both real estate and stock prices:



(Figure 1: S&P CoreLogic Case-Shiller Home Price Index)

National U.S. home prices escalated by approximately 40% between 2020 and 2022 according to the S&P CoreLogic Case-Shiller Index.



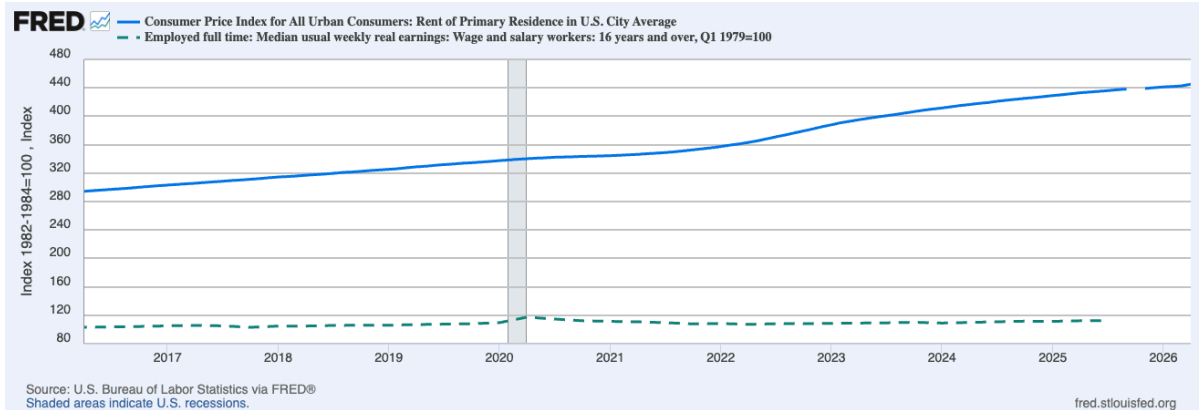
(Figure 2: S&P 500 Market Index Recovery)

The S&P 500 nearly doubled from its March 2020 trough to its early 2022 peak.

While this rapid appreciation superficially signaled economic strength, the underlying expansion primarily benefited institutional entities rather than average citizens. The results from an international empirical study on housing prices confirm that the real interest rate imposes a negative and significant effect on house price growth rates after controlling for economic growth factors, unemployment factors, and cross-country fixed effects. The empirical result of the five housing markets shows that a 1% fall in the real interest rate caused a 1.5% increase in house prices, *ceteris paribus*, in this period (Chuang, 2021).

Simultaneously, institutional buyers (firms owning over 100 private houses) and private investors (owning less than 5 private houses) utilized low-cost capital to aggressively purchase single-family housing inventory, a trend verified in market data by Srikant (2025) and the National Association of Realtors.

The increase in housing wealth can stimulate additional consumption among existing homeowners, either because they feel wealthier or by relaxing borrowing constraints (Guren et al., 2021; Aditya et al., 2022). Conversely, ordinary working-class households were adversely impacted by this overheated market. Because U.S. Bureau of Labor Statistics data indicates that national compensation failed to keep pace with asset inflation, as shown in Figure 3, a deep economic chasm formed between property owners and renters. Rather than benefiting from capital gains, the working class suffered from an accompanying surge in residential rents as higher property valuations were passed down to tenants. Ultimately, this profound decoupling of household income from asset prices underscores an unsustainable economic dynamic driven not by organic performance, but by artificially suppressed interest rates, according to the European Central Bank (Felici, 2022).



(Figure 3: Real Compensation vs. Asset Price Inflation)

Behavioral economics proposed that consumers exhibit a distinct asymmetric reaction to nominal versus real losses—a phenomenon rooted in loss aversion (Krastev, 2021) and the money illusion (Tversky, 1997). While individuals frequently tolerate negative real interest rates (wealth erosion via inflation) when nominal balances appear stable or growing, breaking below the nominal 0% threshold represents a qualitative shift.

When nominal interest rates turn negative, the public perceives—which in turn impacts demand—the policy not as a neutral macroeconomic adjustment, but as an institutional penalty or direct erosion of capital. Historically, institutional investors and large hedge funds have accepted negative nominal returns on high-volume deposits as a premium paid for liquidity and security. Commercial banks, though reluctant, passed negative interest rates as custodian fees onto their corporate clients (Michaelis, 2023) to ensure their profit margins, who agreed with it. In contrast, retail consumers and small businesses exhibit a strong aversion to negative nominal returns, known as the asymmetric bias of loss aversion. The effect is especially pronounced at the individual level, where instinct rather than mathematical calculations guides decisions, even if the public understands the difference between nominal and real interest rates (Shafir, 1997).

Instead of increasing discretionary spending, risk-averse households facing direct and possible capital erosion frequently contract their lifestyle expenditures (Stall, 2023). To meet long-term financial milestones and retirement targets, consumers may increase their savings rate to compensate for the institutional degradation of their principal capital. The liquid capital that does leave the banking system is unlikely to flow entirely into productive consumer spending. Instead, it tends to seek refuge in scarce alternative assets, including equities, real estate, or non-fiat commodities. This capital migration risks inflating hyper-volatile asset bubbles. Ultimately, the enforcement of a boundary-free negative interest rate framework via a mandatory retail CBDC risks destabilizing the foundational civic trust required for fiat currency systems, potentially leading to systemic volatility.

The legal and social resistance to negative nominal retail rates is highlighted by landmark judicial rulings, such as Germany's Federal Court of Justice (BGH) decision regarding retail "custody fees." The court determined that imposing negative nominal rates on standard retail deposits contradicted the foundational legal definition of asset preservation, illustrating the deep-seated institutional and public commitment to the nominal zero barrier. During the NIRP experiments in Europe and Japan (2014–2016), commercial banks largely acted as an economic buffer. Fearing mass deposit flight and severe reputational damage, commercial institutions chose to absorb the costs of negative central bank rates within their own net interest margins rather than passing them directly to household checking accounts (Abadi, Brunnermeier, & Koby, 2023).

A retail CBDC deployed within a cashless ecosystem fundamentally alters this dynamic. By establishing a direct financial relationship between the citizen and the central bank, the commercial banking buffer can be bypassed. Furthermore, the elimination of physical cash removes the consumer's traditional mechanism of evasion (the option to withdraw liquidity), ensuring the direct transmission of negative rates to household wealth.

4.2 Transaction Efficiency, Accessibility, and Targeted Stimulus

While critics focus on extreme negative rate scenarios, macroeconomic and monetary policy literature highlights substantial operational benefits that retail CBDCs deliver over legacy systems.

Financial inclusion is one of the most frequently cited social justifications for retail CBDC issuance, particularly in emerging and developing economies. Central banks in developing countries tend to motivate retail CBDC primarily focus around financial inclusion and payment efficiency, in contrast to developed-country motivations centered on efficiency, security, and resilience (Tang, 2025). The scale of the underlying problem is substantial: the World Bank estimates that roughly 1.4 billion adults globally remain unbanked, and even within the euro area the ECB reports that nearly one in five adults lacks a debit card, credit card, or payment account (Bernardo, 2025).

"Loosely coupled" wallet architectures that do not require a full commercial bank relationship, combined with offline transaction capability, are the two design features most consistently linked to inclusion outcomes in this literature. The Bank for International Settlements' Project Polaris frames offline functionality explicitly as a financial- and digital-inclusion tool, particularly for populations affected by unreliable connectivity or infrastructure (BIS, 2024). Field implementations reinforce this: pilot deployments with West African central banks report that tiered identification — allowing onboarding without full documentary KYC — combined with biometric, offline-capable hardware wallets has enabled access for rural women, smallholder farmers, and informal traders who had previously been excluded due to lack of formal identification or smartphone access (Paycode, 2025). At a more theoretical level, CBDC access can incentivize previously unbanked households to open bank accounts in order to reach CBDC wallets. This in turn allows them to build a credit history and potentially access lower-cost credit — an inclusion channel that operates even before large-scale CBDC circulation occurs (Tan, 2023).

This dynamic is not unconditional, however: the same modeling literature notes that inclusion gains materialize only when CBDC is sufficiently efficient as a means of payment, preserves anonymity, or offers a favorable risk-adjusted return relative to deposits.

Country-level pilots illustrate how these mechanisms translate into practice. The Bahamas' Sand Dollar, the world's first fully implemented retail CBDC, was designed explicitly to solve a two-decade-old financial exclusion problem rooted in the country's geography. With nearly 700 inhabited islands, many too small to sustain a bank branch, and financial services routinely disrupted by hurricanes, the Central Bank of the Bahamas built Sand Dollar to extend regulated payment access to unbanked and underbanked communities without requiring a traditional account relationship (Central Bank of the Bahamas, et al. 2025). Nigeria's eNaira pursued the same goal at a much larger scale, targeting a population in which roughly 60 percent of Nigerians lacked access to financial services. The Central Bank of Nigeria's lowest KYC tier requires only a verified phone number, with wallet and transaction limits rising as users provide additional credentials, and access was later extended to any smartphone user rather than only existing bank customers (Digital Euro Association, 2022; *Ahmad*, 2026). The Bank of Jamaica has pursued a comparable tiered-KYC approach, listing enhanced financial inclusion of the unbanked as the first anticipated opportunity of its CBDC program and pairing it with amendments to national anti-money-laundering law that specifically streamlined account-opening requirements (Bank of Jamaica, Bank of England Chief Economists' Workshop, 2021). China's e-CNY offers a fourth, larger-scale example of the same underlying logic: the People's Bank of China describes the currency as "loosely coupled" with bank accounts, meaning a wallet can be issued without a traditional account as a prerequisite, and supplements this with offline, hardware-based wallets. This extends usability to citizens without smartphones or reliable connectivity, an important feature given that an estimated 300 million people in China still lack stable internet access (Mu, PBOC, 2022; GoldenPi, 2026). A 2022 Postal Savings Bank pilot in rural Ping'an Village, which signed up 40 percent of the local population onto e-CNY and secured acceptance at every local shop, is frequently cited as evidence that this design converts into real rural adoption rather than remaining theoretical (Upstox, 2025).

Taken together, this cross-country evidence supports the claim that the specific design features associated with retail CBDCs — loosely-coupled or tiered-KYC wallets and offline transaction capability — do expand formal payment access for historically excluded populations, and that this is not a single-country phenomenon but a pattern observed across geographically and economically distinct pilots in the Caribbean, West Africa, and East Asia.

Beyond expanding payment access, retail CBDCs enhance monetary policy execution through **programmability**—the capacity to embed rules directly into the currency governing where, when, and how funds are spent. China's e-CNY pilots are the most heavily documented real-world testbed for this feature. Analysts have noted that programmable design permits central banks to distribute consumption vouchers carrying an expiration date, explicitly as a mechanism for timing economic stimulus so that funds are spent within a defined window rather than saved (Capco, 2023). This is not a novel monetary instrument in principle. Literature on expiring digital cash traces the concept to Gesell-style "stamp scrip," and points to a 2009 Taiwanese fiscal stimulus program that distributed roughly \$2.57 billion in

expiring shopping vouchers, which similarly constrained both the timing and the category of permissible spending (Nakazato et al., 2025). China's own regional e-CNY giveaways — including the Shenzhen and Xiong'an lottery-based disbursements of several million dollars each, and subsequent rounds of holiday and consumption subsidies distributed via the e-CNY app — have been cited as evidence of rapid, low-administrative-cost disbursement directly into recipient wallets, with some commentary pointing to reported spending multipliers well above the face value of the voucher itself, although these multiplier estimates originate largely from financial-industry commentary rather than peer-reviewed impact evaluation and should be treated as illustrative rather than conclusive.

It is worth noting that this same programmability, which proponents frame as a tool for effective countercyclical stimulus, is also the feature most frequently flagged as a governance risk in the broader literature. Expiration dates, category restrictions, and geofencing all require a central authority to define and enforce "acceptable" uses of money, and critics — including human-rights-focused trackers of China's CBDC rollout — argue that the same infrastructure that enables targeted stimulus could equally enable targeted account freezes or conditional disbursement tied to political behavior (Human Rights Foundation, 2025). A balanced treatment of the targeted-stimulus benefit should therefore present it alongside this design-level trade-off rather than in isolation, which this review will discuss in more detail in the following section.

5. POLITICAL DEBANKING

The socio-legal literature surrounding programmable currency protocols frequently centers on the tension between state regulatory capacity and fundamental civil liberties. At the core of this debate is the technical architecture of CBDCs. It allows for logic-based conditions—such as expiration dates, geographical boundaries, or merchant restrictions—to be embedded directly into the medium of exchange at the protocol level (Auer et al., 2022). Scholars argue that this shift from transactional anonymity to programmable ledger technology alters the legal nature of currency, effectively transforming money from an absolute property right into a conditional license to spend (Pistor, 2019). While proponents suggest programmability offers targeted monetary policy tools, critical legal theory highlights that removing the administrative friction inherent in traditional banking systems consolidates unprecedented enforcement power within the state apparatus (Goodell & Aste, 2022).

A primary focus within civil liberties literature is the potential for automated compliance mechanisms to bypass traditional judicial oversight. In conventional banking frameworks, freezing an individual's assets generally requires administrative coordination, adherence to statutory procedures, or independent judicial review, which introduces a protective delay or "friction" for the citizen (Zetzsche et al., 2023). Conversely, sovereign smart contracts allow for the instantaneous restriction of funds without requiring the cooperation of commercial financial intermediaries (Group of Thirty, 2020). Legal analysts note that this architectural capability facilitates streamlined political debanking, enabling the exclusion of targeted

individuals or groups from the formal economy based on systemic algorithms rather than individual adjudicated guilt (Omarova, 2021).

The 2022 Canadian "Freedom Convoy" serves as a critical empirical case study within this literature, representing a real-world proof-of-concept for the weaponization of digital financial infrastructure. During this event, the invocation of the Emergencies Act allowed the federal government to bypass standard judicial pipelines and freeze the bank accounts of protesters and donors directly through executive directive (Public Order Emergency Commission, 2023). Although a subsequent judicial review ruled the invocation unlawful and a violation of the Canadian Charter of Rights and Freedoms, the incident highlighted how rapidly digital financial rails can be closed during political crises. The use of emergency financial measures demonstrated that the digital financial system can be deployed as an instrument of immediate state coercion, illustrating that retrospective judicial corrections often occur too late to mitigate immediate economic exclusion.

Legal and technical scholars utilize this precedent to illustrate the fragility of statutory privacy guarantees within centralized digital architectures. Research indicates that built-in privacy safeguards or structural firewalls are highly vulnerable to legislative override or executive amendment during perceived national emergencies. Consequently, a significant consensus within civil liberties literature posits that without the alternative economic "escape valve" of anonymous physical cash, the total transition to a CBDC framework risks funneling populations into a state-managed compliance ecosystem, where economic participation becomes a revocable privilege rather than an unalienable right.

6. CONCLUSION

Ultimately, the synthesized literature presents a nuanced evaluation of a fully digitized financial ecosystem governed by retail CBDC. While critical warnings highlight significant socio-economic risks—including the potential erosion of transactional privacy, volatile behavioral responses to unconstrained negative interest rates, and accelerated state enforcement mechanisms—these concerns are met with substantive counter-arguments and technical solutions.

Privacy-preserving mechanisms such as "managed anonymity" demonstrate that semi-privacy can be secured for daily retail transactions. On the monetary front, retail CBDCs offer clear efficiency gains, including lower transaction costs, broadened financial inclusion for underbanked groups, and precision tools for targeted fiscal stipends. Furthermore, as the non-uniqueness argument illustrates, state financial oversight is already embedded within existing electronic payment frameworks; a CBDC transition streamlines administrative execution but does not inherently redefine state-private boundaries, provided that strict legal frameworks and judicial protections are implemented. As central banks continue testing digital fiat currencies, future scholarship must closely evaluate empirical operational data from emerging pilots to ensure technical designs and statutory safeguards effectively balance payment innovation with civil liberties.

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