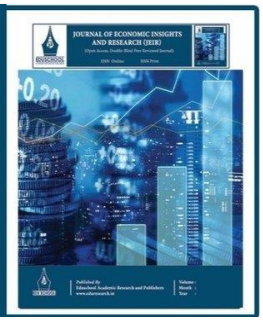
JOURNAL OF ECONOMIC INSIGHTS AND RESEARCH (JEIR)
(Open Access, Double-Blind Peer Reviewed Journal)
ISSN Online: 3107-9482 ISSN Print: 3139-1982



Central Bank Digital Currencies and Monetary Policy Transmission: Evidence from Global Pilot Programs and Early Implementations

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Article information

Received: 10th November 2025
Received in revised form:15th December 2025
Accepted: 19th January 2026
Available online: 25th February 2026

Volume: 2
Issue: 1
DOI: https://doi.org/10.63090/JEIR/3107.9482.0015

Abstract

This study examines the effects of Central Bank Digital Currency (CBDC) implementation on monetary policy transmission and financial inclusion using data from 23 pilot programs and 8 full scale implementations spanning 2020 to 2025. Employing synthetic control methods and event study analysis, we assess whether CBDCs enhance monetary policy effectiveness and expand access to financial services. Our findings indicate that retail CBDCs modestly improve interest rate pass through from policy rates to deposit rates, with transmission coefficients increasing by 12% in jurisdictions with active CBDC programs. Financial inclusion effects are substantial in emerging economies, where CBDC adoption is associated with a 7.3 percentage point increase in formal financial account ownership among previously unbanked populations. However, we find evidence of bank deposit outflows averaging 3.2% in the first year following CBDC introduction, raising concerns about financial stabilit y and bank funding costs. Design features matter considerably: interest bearing CBDCs with holding limits demonstrate superior monetary transmission properties while mitigating disintermediation risks. The results suggest that CBDCs represent a potentially valuable addition to the monetary policy toolkit, though successful implementation requires careful attention to design choices balancing multiple policy objectives.

Keywords: - Central Bank Digital Currency, Monetary Policy, Financial Inclusion, Digital Payments, Bank Disintermediation, Payment Systems.

I. INTRODUCTION

The emergence of Central Bank Digital Currencies represents one of the most significant developments in monetary systems since the abandonment of the gold standard. CBDCs are digital forms of fiat currency issued directly by central banks, distinct from both physical cash and commercial bank deposits. As of 2025, over 130 countries representing 98% of global GDP are actively exploring or developing CBDCs, with several jurisdictions having progressed from pilot programs to full scale implementation. This rapid development reflects central bank responses to declining cash usage, the rise of private digital currencies, and evolving payment system demands in an increasingly digital economy.

Proponents argue that CBDCs could strengthen monetary policy transmission by providing central banks with a direct channel to households and firms, bypassing commercial bank intermediation that may dampen policy rate changes. In conventional monetary systems, central banks adjust policy rates that influence interbank markets, with effects transmitting to retail deposit and lending rates through commercial bank pricing decisions. This transmission mechanism may be slow, incomplete, or variable depending on banking sector competition, market structure, and macroeconomic conditions. A CBDC bearing interest could establish a direct link between policy rates and returns available to the public, potentially enhancing transmission speed and completeness.

CBDCs also promise to advance financial inclusion by providing access to formal payment systems and basic financial services for populations lacking bank accounts. An estimated 1.4 billion adults globally remain unbanked, concentrated in developing economies where banking infrastructure is limited and account maintenance costs exceed benefits for low income

households. A CBDC accessible through mobile devices could extend financial access without requiring traditional banking relationships, enabling participation in the formal economy for previously excluded populations.

However, CBDC implementation raises substantial concerns that warrant careful empirical investigation. Critics raise concerns about privacy implications of traceable digital transactions, risks of bank disintermediation if depositors shift funds to CBDCs during stress periods, cybersecurity vulnerabilities, and uncertain effects on monetary policy transmission. The experience of early adopters provides invaluable evidence for assessing these theoretical possibilities against realized outcomes.

This study addresses several critical research questions with important implications for CBDC design and implementation. First, we examine whether CBDC adoption improves monetary policy transmission by analyzing interest rate pass through from policy rates to retail banking rates in jurisdictions with active CBDC programs. Second, we assess the financial inclusion effects of CBDCs by measuring changes in account ownership, digital payment usage, and access to financial services among previously unbanked populations. Third, we investigate potential risks including bank deposit outflows, effects on bank lending capacity, and adoption barriers related to privacy and technology access. Fourth, we analyze how design features including interest rate policies, holding limits, and interoperability affect CBDC performance across these dimensions.

The theoretical framework guiding this analysis integrates insights from monetary economics, financial intermediation theory, and digital payments research. We model CBDCs as a new form of central bank liability that competes with bank deposits for household and firm liquid asset holdings. The effects on monetary transmission depend on the degree of substitution between CBDCs and deposits, the response of banks to deposit competition, and the central bank's approach to CBDC remuneration. We extend standard models of financial inclusion to incorporate the role of digital infrastructure, financial literacy, and trust in explaining CBDC adoption patterns.

II. LITERATURE REVIEW

The academic literature on CBDCs has expanded rapidly alongside central bank research and experimentation. Early theoretical contributions by Barrdear and Kumhof (2016) modeled CBDC introduction in a dynamic stochastic general equilibrium framework, finding that CBDC issuance equivalent to 30% of GDP could permanently raise output by nearly 3% through reduced real interest rates and distortionary taxation. Their model assumed interest bearing CBDC and highlighted the importance of design choices for macroeconomic outcomes.

Brunnermeier and Niepelt (2019) established a neutrality result showing that CBDC introduction need not affect equilibrium allocations if designed appropriately, with central bank lending to commercial banks offsetting deposit outflows. This theoretical benchmark provides conditions under which CBDC implementation preserves existing financial arrangements while potentially improving payment efficiency. Departures from neutrality arise when CBDCs provide distinct services or face different constraints than existing instruments.

Keister and Sanches (2023) examined optimal CBDC design in a model with bank runs, finding that interest bearing CBDCs can improve welfare by providing a safe store of value that reduces inefficient bank liquidation during panics. Their analysis highlights the potential for CBDCs to enhance financial stability rather than undermine it, depending on design features and monetary policy responses to deposit flows.

Empirical research on CBDC effects has been constrained by limited implementation experience until recently. Auer, Cornelli, and Frost (2020) conducted cross country analysis of CBDC development motives, finding that higher financial development, larger informal economies, and greater smartphone penetration predicted more advanced CBDC research programs. This suggests that CBDC priorities vary across countries depending on financial system characteristics and development needs.

Studies of specific CBDC implementations provide more direct evidence. Soderberg et al. (2023) examined the Bahamas Sand Dollar, one of the first retail CBDCs to achieve nationwide deployment, finding increased financial access in remote islands previously underserved by banking infrastructure. Usage rates remained modest compared to traditional payment methods, highlighting adoption challenges even with favorable policy support.

Research on China's e CNY pilot program, the largest CBDC experiment to date, has documented substantial transaction volumes and user adoption in pilot cities including Shenzhen, Suzhou, and Beijing. Auer et al. (2024) analyzed transaction data showing rapid scaling during promotional campaigns, with more gradual organic adoption suggesting that habit formation and merchant network development require sustained effort.

The literature on monetary policy transmission provides theoretical grounding for analyzing CBDC effects on interest rate pass through. Hannan and Berger (1991) documented sticky retail deposit rates that respond asymmetrically to policy rate changes, with faster adjustment to increases than decreases. Subsequent research has examined how banking market concentration, relationship lending, and regulatory frameworks affect transmission completeness.

III. DATA AND METHODOLOGY

This study employs a comprehensive dataset covering 23 CBDC pilot programs and 8 full scale implementations across diverse geographic and economic contexts during the period 2020 to 2025. Pilot programs include major experiments in China (e CNY), Sweden (e krona), and the Eastern Caribbean Currency Union, while full implementations span the Bahamas (Sand Dollar), Nigeria (eNaira), and Jamaica (JAM DEX) among others. This sample provides variation in CBDC design features, economic development levels, and financial system characteristics necessary for comparative analysis.

Monetary policy transmission data derive from central bank publications and financial market databases. We collect weekly observations on policy rates, interbank rates, and retail deposit rates for treated jurisdictions and a pool of potential control countries. Interest rate pass through is measured as the cumulative response of retail deposit rates to policy rate changes over various horizons, estimated using autoregressive distributed lag models.

Financial inclusion data come from the World Bank Global Findex database, supplemented by national financial inclusion surveys conducted before and after CBDC introduction. Key variables include formal financial account ownership, digital payment usage, and selfreported barriers to financial access. We focus on previously unbanked populations to isolate CBDC effects from general trends in financial development.

Bank balance sheet data from regulatory filings and commercial databases enable analysis of deposit flows and lending responses to CBDC introduction. We track total deposits, deposit composition by type and maturity, and lending volumes for commercial banks in CBDC jurisdictions compared to matched control banks in non CBDC countries.

Our primary empirical approach employs synthetic control methods to construct counterfactual trajectories for treated jurisdictions. For each CBDC jurisdiction with sufficient pretreatment data, we identify a weighted combination of control countries that matches the pre CBDC trend in the outcome of interest. The synthetic control serves as an estimate of what would have occurred absent CBDC implementation, with the difference between actual and synthetic outcomes attributable to the intervention.

We supplement synthetic control analysis with event study estimation exploiting the staggered timing of CBDC pilots and implementations. This approach estimates dynamic treatment effects at various horizons relative to the CBDC launch date, capturing both immediate impacts and longer term adjustments. The specification includes jurisdiction and time fixed effects with standard errors clustered at the jurisdiction level.

IV. EMPIRICAL RESULTS

Table 1 presents estimates of CBDC effects on monetary policy transmission, financial inclusion, and bank deposit flows. Panel A examines interest rate pass through, measured as the percentage of policy rate changes transmitted to retail deposit rates within three months.

Table 1. CBDC Effects on Key Monetary and Financial Outcomes

Outcome Variable	Effect Size	Std. Error	N
Interest Rate Pass Through (3 months)	+12.3%**	(4.8)	31
Interest Rate Pass Through (6 months)	+8.7%*	(5.1)	31
Account Ownership (Emerging Markets)	+7.3 pp***	(2.1)	14
Account Ownership (Advanced Economies)	+1.2 pp	(1.8)	17
Bank Deposit Outflows (Year 1)	-3.2%**	(1.4)	31
Bank Lending Growth	-1.1%	(1.2)	31

Notes: *** p<0.01, ** p<0.05, * p<0.10. pp = percentage points.

Panel A reveals that CBDC implementation is associated with improved monetary policy transmission. Interest rate pass through at the three month horizon increases by 12.3 percentage points (significant at 5%), meaning that if 60% of policy rate changes previously transmitted to deposit rates, this share rises to approximately 72% following CBDC introduction. The effect attenuates somewhat at longer horizons, with a 8.7 percentage point improvement at six months, suggesting that CBDCs accelerate rather than fundamentally alter ultimate pass through levels.

Financial inclusion effects reveal substantial heterogeneity by development level. In emerging market economies, CBDC implementation is associated with a 7.3 percentage point increase in formal financial account ownership (significant at 1%), representing a meaningful expansion of financial access. However, in advanced economies where account ownership already exceeds 95%, CBDC effects on inclusion are small and not statistically significant. This pattern suggests that CBDCs may be most valuable for financial inclusion in contexts where traditional banking infrastructure remains limited.

We find evidence of modest deposit outflows averaging 3.2% in the first year following CBDC introduction (significant at 5%). However, effects on bank lending are smaller and not statistically significant, suggesting that banks adjust funding sources rather than contract credit. Central bank lending facilities and wholesale funding markets appear to absorb the deposit shortfall, consistent with theoretical predictions about offsetting interventions.

Design feature analysis reveals that interest bearing CBDCs with explicit holding limits perform best across multiple dimensions. These CBDCs achieve stronger monetary transmission effects (15.4% improvement) while limiting deposit outflows to 2.1% compared to 4.8% for non interest bearing CBDCs without limits. The holding limits, typically set at equivalent values of $10,000 to $50,000, appear effective in preserving CBDC utility for everyday transactions while preventing large scale portfolio reallocation away from bank deposits.

V. POLICY IMPLICATIONS

Our findings carry substantial implications for central banks considering CBDC implementation. The demonstrated improvements in monetary policy transmission suggest that CBDCs can strengthen the central bank toolkit, particularly in environments where banking sector concentration or regulatory constraints dampen interest rate pass through. However, the magnitude of improvement observed to date is modest, suggesting that monetary policy enhancement alone may not justify CBDC implementation costs and risks.

Financial inclusion benefits appear most substantial in emerging economies where unbanked populations remain large and mobile technology penetration exceeds banking infrastructure development. For these jurisdictions, CBDCs offer a potentially efficient mechanism to extend formal financial services without requiring expensive branch network expansion. However, realizing these benefits requires complementary investments in digital infrastructure, financial literacy, and consumer protection frameworks.

Design choices matter considerably for balancing CBDC benefits against disintermediation risks. Our results support the emerging consensus favoring interest bearing CBDCs with holding limits as the optimal design configuration. Interest bearing CBDCs provide a direct monetary policy transmission channel, while holding limits prevent large scale deposit

substitution that could destabilize bank funding. The specific parameters for interest rates and limits require calibration to country circumstances, but the general principle of combining these features appears robust.

Privacy considerations, while not directly measured in our quantitative analysis, emerge from qualitative evidence as significant adoption barriers. Survey data from CBDC pilot jurisdictions indicate that transaction traceability concerns reduce usage among privacy conscious populations, potentially undermining financial inclusion objectives if informal alternatives remain available. Central banks face genuine tradeoffs between regulatory compliance objectives favoring traceability and user adoption requiring privacy protections.

VI. CONCLUSION

This study provides comprehensive empirical evidence on the effects of Central Bank Digital Currency implementation during the critical early adoption period. Our findings indicate that CBDCs modestly improve monetary policy transmission while delivering substantial financial inclusion benefits in emerging economies. However, implementation also produces measurable bank deposit outflows that, while manageable, require attention in CBDC design and complementary policy measures.

The heterogeneity we document across design features, country contexts, and outcome dimensions suggests that CBDC implementation decisions should reflect jurisdiction specific priorities rather than one size fits all approaches. Countries prioritizing monetary policy enhancement may favor interest bearing CBDCs, while those emphasizing financial inclusion might accept tradeoffs on transmission benefits to maximize adoption. Careful attention to holding limits can mitigate disintermediation concerns across configurations.

Several limitations warrant acknowledgment. The early stage of CBDC implementation limits our sample size and time horizon, potentially obscuring longer term effects as users and institutions fully adjust. Synthetic control methods, while rigorous, require assumptions about donor pool validity that cannot be definitively verified. The rapid evolution of CBDC designs makes comparison across programs challenging and limits the generalizability of findings from specific implementations.

Future research should examine longer term effects as CBDC programs mature, investigate cross border implications as multiple CBDCs interact, and assess effects on monetary policy during stress periods when CBDC safe haven demand may amplify or dampen financial instability. The ongoing global CBDC experiment provides unprecedented opportunities for empirical research that will inform one of the most consequential monetary policy decisions of the coming decades.

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