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Retail cryptocurrency adoption and the progress of Central Bank Digital Currencies

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ABSTRACT

This paper studies whether retail cryptocurrency adoption nudges governments toward advancing Central Bank Digital Currency (CBDC) projects. Using a balanced panel of 21 countries for 2019–2024, we measure CBDC progress with an ordered outcome and retail crypto adoption with average daily active users of crypto exchange apps per million people. Ordered probit models with country and year fixed effects show that higher retail adoption strongly and robustly correlates with advancing along the CBDC lifecycle. Coefficients on retail crypto adoption remain positive and statistically significant across progressively richer specifications. Addressing endogeneity with an instrument based on internet disruptions yields consistent results in 2SLS and CMP frameworks; propensity-score matching and Oster (2019) stability tests corroborate the findings. Robustness checks (lagged adoption, nonlinearities, and influential-country exclusions) and a dominance analysis further support the main result. Interaction models suggest that the burden of regulation and tax disincentives weaken the link between crypto adoption and CBDC progress, whereas stronger auditing/reporting standards strengthen it. Overall, the evidence is consistent with a "competitive public option" channel in which retail crypto activity increases the salience and possibly the urgency of CBDC initiatives

1. Introduction

Retail use of cryptocurrencies has expanded rapidly in many jurisdictions while central banks have intensified work on Central Bank Digital Currencies (CBDCs) (Illes et al., 2025). This twin evolution raises a central policy question: *does bottom-up retail crypto adoption pressure authorities to advance CBDC projects?* We address this question by aligning a behavior-based measure of retail crypto activity with a staged measure of CBDC progress and studying their relationship across a balanced panel of 21 economies from 2019 to 2024. The outcome variable tracks movement along the CBDC lifecycle: no project → research → pilot → "live", while the key regressor captures average daily active users (DAUs) of crypto-exchange apps per million residents. This design allows us to connect real-time retail engagement with policy progression, rather than relying on case studies or one-off policy announcements.

Two features motivate our approach. First, behavior-based adoption data better reflect the intensive margin of participation than download counts or sporadic surveys (Auer et al., 2022; Harari et al., 2016). Our main regressor aggregates DAUs across 200 + identified exchange applications from Sensor Tower, excludes duplicates, is annualized, and is population-normalized, yielding

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a cross-country comparable measure that is highly dispersed in practice (Chainalysis, 2023). Second, the Atlantic Council CBDC tracker can be mapped to an ordered outcome that captures the sequential nature of CBDC workstreams, enabling inference about progression up to the launch stage (Atlantic Council n.d.). These data resolve a measurement gap in the literature by bringing high-frequency usage and policy staging into the same panel.

The research gap is both empirical and conceptual. Much of the CBDC literature focuses on design trade-offs (access, remuneration, intermediation, privacy) or on country case studies, leaving limited cross-country evidence on whether retail crypto engagement is systematically associated with advancement in CBDC programs once institutional context is considered (Illes et al., 2025). We fill this gap by combining the CBDC lifecycle variable with the retail crypto usage measure and conditioning on a rich set of macro-institutional covariates drawn from the World Economic Forum's Global Competitiveness Report (WEF/GCR), including macro environment, affordability/availability of financial services, bank soundness, legal adaptability, energy regulation, and proxies for government capacity, as well as geopolitical risk.

Prior research by international policy institutions has substantially advanced (i) descriptive mapping of CBDC projects and design considerations and (ii) measurement of retail crypto activity and its drivers (e.g., Atlantic Council n.d.; Bank for International Settlements and Committee on Payments and Market Infrastructures BIS/CPMI, 2020; Bank for International Settlements, 2021, 2022; International Monetary Fund and Financial Stability Board IMF-FSB, 2023; Illes et al., 2025; Auer et al., 2025). However, this evidence base is largely descriptive, survey-based, or case-study oriented, and it rarely aligns behavioral, retail-level adoption data with a staged CBDC policy outcome in a unified panel suitable for cross-country inference. Our contribution is therefore not to re-state known design trade-offs, but to provide systematic, mechanism-consistent evidence on whether bottom-up retail crypto engagement is associated with top-down advancement in CBDC programs once institutional capacity and legacy-rail performance are accounted for.

Methodologically, we estimate ordered probit models with country and year fixed effects to respect the ordinal nature of the outcome and the panel structure. To probe endogeneity, we use an external instrument based on internet disruptions in a 2SLS framework and a conditional mixed process system; we then assess selection on unobservables with Oster (2019) and provide a non-parametric cross-check via propensity-score matching. We complement the baseline with sensitivity tests (functional form, lags, influential-case exclusions), additional controls (technological readiness, broadband, infrastructure, trade frictions, government adaptability), a dominance analysis (relative importance of regressors), and moderation tests that examine how regulatory burden, tax incentives, and auditing standards shape the crypto to CBDC link.

Our preview of results is fourfold. First, the baseline ordered-probit estimates show that higher retail crypto adoption is positively and significantly associated with advancement along the CBDC lifecycle, and model fit improving accordingly. Second, the association is robust to richer conditioning, adding technological readiness, broadband penetration, infrastructure quality, and government adaptability. Third, endogeneity checks confirm the direction and significance of the relationship: instrumenting crypto adoption with internet disruption yields lower but also positive coefficients; the Oster delta indicates that selection on unobservables would need to rival selection on observables to nullify the effect; and propensity score matching shows no adverse selection effect. Fourth, structure matters: dominance results show that institutional fundamentals explain much of the cross-country variation overall, while moderation results indicate that the crypto-CBDC link is attenuated by heavy regulatory burden and very investment-friendly tax regimes, and amplified by strong auditing/reporting standards.

These findings have concrete policy implications. Behavior-based crypto adoption measures can serve as early warning indicators for CBDC workstreams, helping authorities time consultations, proofs-of-concept, and pilots (Financial Stability Board (FSB), 2023; International Monetary Fund and Financial Stability Board (FSB), 2023). However, responsiveness to retail signals is conditional on state capacity and governance: legal adaptability, secure infrastructure, and strong auditing standards facilitate translation from market signals to policy movement, whereas heavy regulatory burdens can blunt it. The results also emphasize the sequencing logic of CBDC programs: the positive lagged effect suggests that surges in retail adoption precede, not merely accompany, policy progression from no project to research and pilot within our window.

The paper contributes to the literature in several ways. First, we introduce a mechanism based conceptual framework that treats CBDC advancement as a sequential policy decision (no project → research → pilot → live), where retail crypto adoption affects policymakers' incentives (competition/sovereignty, modernization/inclusion, consumer protection/stability, and compliance/data governance) and where institutional capacity determines feasibility and the speed of progression (Tourpe et al., 2023; Dixit and Pindyck, 1994; Illes et al., 2025). Wet provides cross-country evidence that retail crypto engagement is a meaningful predictor of CBDC progression up to the live stage, after accounting for macro-institutional context (Atlantic Council n.d.; Tourpe et al., 2023).

Second, we contribute measurement alignment by combining (i) a behavior-based retail adoption metric, i.e., population normalized daily active users of crypto exchange apps (Auer et al., 2025), with (ii) an ordered CBDC lifecycle outcome constructed from the Atlantic Council tracker (Atlantic Council n.d.). This linkage reduces reliance on coarse proxies (e.g., downloads or sporadic surveys) and allows us to study progression rather than one off announcements.

Third, we contribute new cross-country evidence on structural asymmetries: our dominance and moderation analyses show that retail adoption's relative importance is substantially higher in developing economies than in advanced economies, and that governance and political economy frictions (regulatory burden, tax environment, auditing/reporting capacity) systematically shape the adoption to policy link (Corbet et al., 2024; Ozili 2023a, 2023b; Allen et al., 2022).

The remainder of the paper proceeds as follows. Section 2 situates the study in the literature, clarifies theoretical channels, and develops hypotheses. Section 3 describes the data, key variables, controls, and estimation model. Section 4 presents baseline results, Section 5 addresses endogeneity, and Section 6 reports sensitivity checks. Section 7 provides dominance and moderation analyses that uncover mechanisms and heterogeneity. Section 8 concludes with policy implications, limitations, and directions for future research.

2. Related literature

2.1. Conceptual foundations

CBDCs and cryptocurrencies represent distinct phenomena in the evolving digital-money landscape. A CBDC is a public monetary instrument, an extension of central bank money into digital form, whose development reflects a staged policy process shaped by mandate, design choices, and implementation constraints. By contrast, retail crypto adoption reflects bottom-up private-sector uptake of crypto-assets and stablecoin-mediated rails, often occurring outside traditional banking channels and evolving rapidly with market conditions. Our study links these two domains by asking whether variation in retail crypto adoption is systematically associated with progression in CBDC development once institutional capacity, infrastructure, and legacy-rail performance are accounted for.

On the CBDC side, the literature positions retail CBDCs at the intersection of public-money provision, retail payments competition, and digital-infrastructure policy. Foundational analyses emphasize that a retail CBDC may improve payment efficiency, resilience, and inclusion while preserving monetary and financial stability, privacy, and the unit-of-account role of central bank money, with outcomes depending on key design levers. These levers include access modalities (account- vs token-based), intermediation models, remuneration and holding limits, and offline functionality (Davoodalhosseini et al., 2020; Bindseil, 2020; Mu and Mu, 2022; Zhang and Huang, 2022). A complementary body of survey and review work documents how CBDC agendas have shifted from conceptual analysis to proofs-of-concept and pilots, and highlights interoperability, cybersecurity, governance, and cross-border considerations as constraints that shape sequencing and speed (Hoang et al., 2023; Dionysopoulos et al., 2024; Carvalho Silva and Mira da Silva, 2025). Technical research further sharpens the feasibility frontier by comparing platform options (e.g., DLT versus centralized cores), clarifying privacy–audit trade-offs, and examining operational resilience and energy-efficiency constraints. These features determine what can be implemented at scale (Lee et al., 2021; Guo et al., 2024; Dionysopoulos and Giaglis, 2022). Together, this CBDC-focused literature motivates treating CBDC development as progression along a staged policy pipeline (rather than as a single "yes/no adoption" outcome) and motivates conditioning on governance and infrastructure fundamentals when relating private adoption pressures to public policy movement.

Macroeconomic theory provides additional foundations for interpreting CBDC development as a policy choice with general-equilibrium implications. Core contributions formalize a CBDC as risk-free public money that can compete with cash and bank deposits, affecting money demand, bank funding, and monetary policy transmission. Early macro analyses highlight how remuneration, access conditions, and holding limits shape welfare and the degree of deposit displacement by changing the relative attractiveness of public versus private money. Subsequent work emphasizes explicit trade-offs among payment efficiency, privacy/anonymity, and intermediation risk, often under network forces that amplify adoption once a payment instrument gains traction (Agur *et al.*, 2022). Related monetary theory shows that reallocations between private and public money can be neutral under specific institutional and balance-sheet implementations, underscoring why design and governance details matter for avoiding destabilizing effects on credit provision. This strand reinforces our empirical emphasis on CBDC progression as a sequential policy outcome that reflects ongoing trade-offs between public-interest benefits and legal, operational, and intermediation constraints.

A closely related political-economy strand frames CBDC development as a response to digital currency competition and shifting monetary sovereignty constraints. The digitalization of payments can "unbundle" the roles of money and intensify competition from private digital monies and global stablecoins, potentially giving rise to digital currency areas shaped by platform ecosystems and network effects. These dynamics raise concerns about standards-setting power, interoperability, and the preservation of the unit of account, strengthening policymakers' incentives to consider a public digital alternative that anchors settlement and supports open, competitive payment platforms (Brunnermeier, James, and Landau, 2019; G7 Working Group on Stablecoins, 2019). Policy syntheses similarly argue that CBDCs can serve as public infrastructure that promotes interoperability and mitigates fragmentation, data-silo market power, and currency substitution pressures—linking CBDC agendas to broader governance objectives beyond narrow payment efficiency (Bank for International Settlements, 2021, 2022). These foundations support the "competitive public option" logic and clarify why rising private adoption can be policy-salient.

Classic insights from network economics and platform competition provide a final conceptual layer. Because payment instruments operate as networks, and often as two-sided platforms linking users and merchants, adoption can exhibit feedback loops, tipping dynamics, and path dependence, while interoperability choices shape market structure and lock-in. These foundations help motivate interpreting private adoption of alternative rails as a signal that network effects and platform dynamics are intensifying outside incumbent payment infrastructures, potentially altering the payoff to policy innovation in the public payments layer.

On the crypto adoption side, a growing literature treats retail crypto engagement as both an informational signal and a competitive force that can shift policymakers' cost–benefit calculus. Behavior-based evidence indicates that exchange-app usage is high-frequency, price-sensitive, and skewed toward younger, risk-tolerant users, implying that surges in participation may reflect either unmet demand for faster, cheaper, and programmable payment functionality or, alternatively, an increase in speculative pressures and consumer-protection concerns (Auer et al., 2025). On the competition and sovereignty margin, greater private adoption can weaken central banks' influence over standards and reduce visibility over retail payment flows, motivating a public digital alternative that preserves the unit of account and supports compliance objectives (Bindseil and Pantelopoulos, 2023; Bolt et al., 2022). On the inclusion and modernization margin, retail crypto activity can proxy for frictions in legacy rails, especially in cross-border transfers, remittances, and merchant acceptance, strengthening the case for public digital rails that can interoperate with existing systems and expand access (Foster et al., 2021; Ozili 2023a, 2023b). These arguments yield the core empirical prediction that higher retail crypto adoption should be associated with a higher likelihood of observable advancement along the CBDC pipeline, conditional on background institutional capacity.

Critically, CBDC development is widely characterized as sequential and path-dependent. Authorities typically begin with research and conceptual work (legal analysis, consultation, proofs-of-concept), then progress to pilots (limited-scope testing under controlled conditions), and only subsequently consider launch (Tourpe et al., 2023). This sequencing aligns with a real-options logic under uncertainty: as private adoption and its externalities rise, the option value of experimentation increases, encouraging policymakers to "exercise" the research and pilot options when feasible, and potentially the launch option once risks and implementation constraints are better understood (Dixit and Pindyck, 1994). At the same time, cross-country differences in legal adaptability, supervisory capability, infrastructure, and administrative agility shape whether the same private-adoption signal can be translated into policy movement, suggesting heterogeneous responses across jurisdictions (Illes et al., 2025). This logic motivates our emphasis on institutional covariates and governance moderators, and it reinforces the appropriateness of modeling CBDC development as ordered progression rather than as a static design choice.

Finally, these conceptual foundations also clarify the key identification challenges that guide our empirical design. Retail crypto adoption and CBDC progression may be jointly influenced by common shocks (e.g., macro conditions and geopolitical risk) and by digital readiness (connectivity and secure infrastructure), while feedback effects (e.g., CBDC news stimulating crypto interest) and measurement error in usage metrics may confound naïve associations. We therefore condition on a rich set of macro-institutional controls, model CBDC development as an ordered policy process with country and year fixed effects, and exploit plausibly exogenous shifts in retail usage to mitigate simultaneity. Taken together, the CBDC design, political-economy, and adoption literatures motivate a testable proposition: as retail crypto adoption rises, the probability that authorities advance from "no project" to "research" and from "research" to "pilot" increases, particularly where institutions and infrastructure are sufficient to translate market signals into feasible policy action.

2.2. Transmission mechanisms

We conceptualize CBDC development (CBDCAD) as a sequential policy choice in which authorities decide whether to advance from stage s (no project / research / pilot) to stage $s + 1$ when the expected net benefit of progressing exceeds the political, legal, and operational costs of doing so. This staging is consistent with the way CBDC projects are typically organized and governed in practice—moving from exploratory research to proofs-of-concept, pilots, and then (conditional on feasibility and mandate) live issuance (Bank for International Settlements and Committee on Payments and Market Infrastructures BIS/CPMI, 2020; Tourpe et al., 2023). Retail crypto adoption can enter this decision calculus by (i) increasing the perceived benefits of a public digital alternative (competition, safety, inclusion, efficiency) and/or (ii) increasing the perceived costs of inaction (loss of standards-setting power, monetary sovereignty concerns, consumer-protection pressures, and supervisory blind spots). At the same time, moving from research to pilot to live issuance requires feasibility conditions—legal authority, supervisory capacity, cybersecurity and operational resilience, digital infrastructure, and governance arrangements—so the same "adoption signal" may translate into different policy responses across jurisdictions. This framework clarifies why we model CBDC development as an ordered lifecycle and why we expect heterogeneity by institutional capacity and governance.

A first channel is the competitive public option / monetary sovereignty mechanism. Rising retail adoption of crypto-assets and stablecoins can shift retail activity toward private balance sheets and standards that operate partly outside the traditional regulatory perimeter, potentially weakening the monetary anchor and fragmenting the retail payments stack. When exchange-app usage intensifies, as proxied by our retail crypto adoption measure (CRPTADP), policy-makers and central banks may face stronger incentives to offer a public option that preserves settlement finality, maintains the unit-of-account function, and reasserts standards-setting capacity in retail payments. A retail CBDC can help "re-anchor" the payments ecosystem by setting interoperability baselines, countering network effects in private token ecosystems, and ensuring that safe public money remains available in digital form. Under this channel, higher CRPTADP should raise the likelihood that authorities move up the CBDC ladder (no project → research → pilot → launch). This interpretation aligns with analyses that motivate CBDCs by competition with unbacked crypto and global stablecoins and by the policy need to safeguard the monetary anchor and the integrity of the payment system (Conlon et al., 2022; Bindseil and Pantelopoulos, 2023; Bolt et al., 2022; Wang and Gao, 2024; BIS, 2022; Auer and Böhme, 2020).

A second channel is the payments modernization and inclusion mechanism. Retail crypto use can be interpreted as revealed preference for faster, cheaper, and more user-friendly payments, especially where legacy rails are slow, expensive, or unreliable, and for improved cross-border functionality (e.g., remittances). In such contexts, rising crypto adoption may signal that the social return to modernizing public digital rails is high. A well-designed CBDC, particularly under an intermediated architecture that leverages private-sector interfaces while providing a robust public settlement layer, can target these frictions through features such as 24/7 availability, offline functionality, interoperability, and low-cost onboarding. Accordingly, policymakers observing higher CRPTADP may accelerate the transition from research to pilot to launch where the perceived payoff is improved payment efficiency and broader access. This motive is emphasized in policy and empirical syntheses, especially for EMDEs where payments frictions and inclusion gaps are often most salient (Ozili 2023a, 2023b; Morales-Resendiz et al., 2021; Foster et al., 2021; Committee on Payments and Market Infrastructures, and World Bank Group CPMI/WB, 2016). In addition, the modernization channel is compatible with evidence that CBDC design and fast payment systems can be complements rather than strict substitutes, and that CBDC projects increasingly incorporate interoperability and cross-border considerations early in the design phase (Aurazo et al., 2024; Reslow et al., 2024; Auer et al., 2021).

A third channel is the stability, consumer-protection, and political-salience mechanism. Episodes of rapid retail entry into crypto, often driven by price run-ups and attention shocks, can increase household exposure to volatility, fraud, and operational failures (including exchange outages, custody vulnerabilities, and stablecoin run dynamics). These risks can raise political salience and strengthen the case for a regulated public alternative that offers a safer digital settlement asset within the sovereign monetary framework. In this view, higher CRPTADP increases the perceived benefit of moving from research into pilots (and potentially launch) to (i) provide a safe settlement asset, (ii) clarify the supervisory perimeter, and (iii) strengthen consumer protection at the retail level. This rationale is consistent with macro-financial assessments of crypto-related vulnerabilities and with policy frameworks emphasizing the financial-stability and consumer-protection implications of crypto-asset growth (Infante et al., 2022; Yousaf and Goodell, 2023; Dehghani et al., 2025; Hacibedel and Perez-Saiz, 2023; Bains et al., 2022; Financial Stability Board (FSB), 2023; International Monetary Fund and Financial Stability Board (FSB), 2023).

A fourth channel is the data governance, payment transparency, and compliance mechanism. Even when public ledgers are traceable in principle, effective supervisory visibility can be limited by pseudonymity, cross-border venue fragmentation, and the weak mapping between on-chain addresses and verified identities. As retail crypto adoption rises, authorities may perceive a widening gap in their ability to monitor retail payment flows for AML/CFT enforcement, tax compliance, fraud detection, and consumer protection. A CBDC can be designed to improve data governance by enabling auditable yet privacy-respecting transaction records (e.g., tiered privacy and conditional disclosure) and by supporting "programmable compliance" features (rules-based reporting thresholds, sanctions screening, risk-based limits), subject to legal safeguards and institutional design choices. Under this mechanism, the adoption–CBDC link should be stronger where institutional auditability and reporting capacity are high, because these environments reduce governance frictions and increase the feasibility of implementing privacy-preserving compliance regimes. Conceptual and applied work on CBDC compliance architectures and auditability supports this channel (Dupuis et al., 2022; Wang et al., 2022; Jabbar et al., 2023), while AML/CFT guidance for virtual assets and digital identity underscores why supervisors may view growing crypto usage as expanding the enforcement challenge (Financial Action Task Force, 2014, 2020, 2021). Recent CBDC policy work also highlights that CBDC data governance requires explicit institutional arrangements and tools to manage the trade-off between data use and privacy protection (Murphy et al., 2024; World Economic Forum, 2020).

Beyond these incentive channels, feasibility, and sequencing constraints condition whether and how quickly authorities can convert the "crypto adoption signal" into CBDC progress. The implementation burden rises sharply when moving from research to pilot and from pilot to launch, as these steps require resilient digital infrastructure (connectivity, secure data centers, and real-time interfaces), robust cybersecurity and operational governance, and cost-effective system design. Because retail crypto usage often piggybacks on the same underlying infrastructure, higher CRPTADP may also proxy for de facto readiness to support CBDC proofs-of-concept and pilots, increasing the probability of progression where complementary capacity is present. Technical assessments of CBDC platforms and energy-efficiency considerations emphasize why infrastructure maturity conditions feasibility and sequencing (Guo et al., 2024; Agur et al., 2023; Dionysopoulos and Giaglis, 2022).

Retail crypto adoption is not monolithic. The same increase in exchange-app activity can reflect different underlying motives, including (i) payment utility (e.g., cross-border transfers and remittances where legacy rails are costly or slow) (Committee on Payments and Market Infrastructures, and World Bank Group CPMI/WB, 2016; Morales-Resendiz et al., 2021; Reslow et al., 2024; Ozili 2023a, 2023b), (ii) speculation/portfolio demand driven by price and attention cycles (Auer et al., 2025), and (iii) integrity- or controls-related motives (illicit finance, tax evasion, or capital-controls circumvention) emphasized in the global AML/CFT and crypto-policy literature (Financial Action Task Force, 2014, 2021; International Monetary Fund and Financial Stability Board IMF-FSB, 2023). Our DAU-based measure (CRPTADP) captures engagement intensity with exchange venues and therefore aggregates across these channels; it does not separately identify the motive of adoption. Importantly, these motives imply divergent (and potentially complementary) policy paths. When adoption rises primarily for payment utility, CBDC progression can complement payments modernization and inclusion objectives (Committee on Payments and Market Infrastructures, and World Bank Group CPMI/WB, 2016; Morales-Resendiz et al., 2021; Reslow et al., 2024). When adoption rises primarily for speculative or integrity-risk reasons, authorities may rationally prioritize regulatory tightening, supervisory oversight, and enforcement (Financial Action Task Force, 2021; International Monetary Fund and Financial Stability Board IMF-FSB, 2023), with CBDC development (if pursued) framed as a medium-term infrastructure option for compliant digital payments rather than the first-best response. We therefore interpret CRPTADP as a policy-salience indicator that can be associated with movement along the CBDC pipeline, while recognizing that the composition of adoption motives can shift the balance between CBDC acceleration and alternative regulatory responses (Financial Stability Board, 2023; International Monetary Fund and Financial Stability Board IMF-FSB, 2023).

Overall, these channels predict a positive marginal association between retail crypto adoption and CBDC advancement: competition/sovereignty and stability considerations raise the policy payoff to CBDC; modernization/inclusion and compliance considerations raise the social payoff; and infrastructure maturity and institutional capacity raise the feasibility of moving from research to pilots and beyond. These mechanisms are not mutually exclusive, and they naturally imply heterogeneity across jurisdictions and across stages of the CBDC lifecycle. Consistent with the broader evidence base, in EMDEs CBDC rationales often emphasize inclusion, remittances, and currency competition, while in advanced economies they tilt toward resilience, privacy, and competition with BigTech/stablecoins within already well-developed legacy rails (Corbet et al., 2024; Laboure et al., 2021; Allen et al., 2022). This mapping is also consistent with our moderation results: the translation of crypto adoption into CBDC progress should be weaker where legal and regulatory frictions are high (a constraints view) and stronger where auditing/reporting capacity is higher (a governance view). Our interaction results with the burden of regulation and auditing/reporting standards align with these predictions, and our controls for legal adaptability, infrastructure, and traditional financial-rail performance help separate crypto-specific incentives from general capacity.

2.3. Hypotheses development

Building on these frameworks, we derive testable hypotheses aligned with our variables and empirical strategy:

H1. : Higher retail cryptocurrency adoption is associated with advancement along the CBDC lifecycle.

As retail crypto adoption increases, the probability that a country moves from no project to research to pilot to launch rises. Retail adoption can heighten competitive and sovereignty pressures from private digital monies; reveal unmet demand for faster/cheaper payments and cross-border functionality; raise financial-stability and consumer-protection concerns; expand AML/CFT and data-governance needs; and coincide with the technological readiness required to experiment, all of which increase the policy payoff to progressing CBDC workstreams (Auer et al., 2025; Bolt et al., 2022; Bindseil and Pantelopoulos, 2023; Wang and Gao, 2024).

H2. : The retail crypto adoption – CBDC association is attenuated where legacy financial rails already perform well, but amplified where macro and digital capacity are stronger.

Specifically, we expect negative moderation by the affordability and availability of traditional financial services because efficient private rails reduce the perceived marginal need to accelerate a retail CBDC (a substitution effect). Conversely, we expect positive moderation by macroeconomic environment and digital/infrastructure readiness, which lower implementation costs and increase the feasibility of pilots (a capacity effect). In addition, geopolitical risk should dampen the link by inducing policy caution. (Morales-Resendiz et al., 2021; Bindseil, 2020; Corbet et al., 2024; Agur et al., 2023; Lee et al., 2021).

H3. : The retail crypto adoption – CBDC association is stronger where governance is adaptive, and auditability is high, and weaker where regulatory frictions or very investment-friendly tax regimes mute policy responses.

Concretely, we expect positive moderation by legal adaptability, auditing/reporting standards, and government adaptability, which reduce policy and implementation frictions and make authorities more responsive to retail signals. We expect negative moderation by the burden of regulation, which elevates procedural costs and slows approvals, and by highly investment-friendly tax incentives, which can lessen the perceived need for a new public option when private investment conditions already support FinTech innovation. (Dionysopoulos and Giaglis, 2022; Wang, Ma and Ren, 2022; Lee et al., 2021; Conlon et al., 2022; Allen, Gu and Jagtiani, 2022; Ozili 2023a, 2023b).

3. Empirical strategy

3.1. Data

We assemble an annual country–year panel for 2019–2024 covering 21 economies: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Israel, Italy, Japan, Mexico, Nigeria, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the United Kingdom, and the United States. The dependent variable (CBDC stage) is sourced from the Atlantic Council CBDC Tracker; the key regressor (retail crypto adoption) derives from Auer et al. (2025)'s BIS/IMF dataset built from Sensor Tower app-usage records; macro-institutional controls come from the World Economic Forum's Global Competitiveness Report (WEF/GCR); and geopolitical risk (GPR) is from Caldara and Iacoviello (2022). All series are merged by ISO-3 country code and calendar year. The resulting panel is balanced (126 observations); variable definitions and sample descriptive statistics appear in Appendix 1 and Tables 1–3 of the manuscript. While the sample size is small (due to the nature of the outcome variable and the condition that data for both key variables

Table 1
Global trends in CBDCAD and CRPTADP around the world (average country values).

Country	CBDC adoption	Cryptocurrency adoption
Argentina	1.00	59.62
Australia	1.33	87.98
Brazil	1.00	25.99
Canada	2.00	86.02
China	2.00	0.05
France	2.00	83.27
Germany	1.00	73.37
India	0.83	6.48
Indonesia	1.00	18.50
Israel	1.66	83.28
Italy	0.33	57.56
Japan	2.00	27.63
Mexico	0.17	18.75
Nigeria	1.45	13.56
Russia	1.17	53.53
Saudi Arabia	2.00	23.78
South Africa	1.83	23.47
South Korea	2.00	105.78
Turkey	1.00	315.11
United Kingdom	1.17	178.59
United States	1.00	164.03
Total average	1.33	71.74

Note: The table reports the general trends of the key variables across all years.

exist across countries) it has the statistical power for credible inference (Long and Freese, 2014). The panel retains its size, with minor variation in some robustness and IV specifications reflecting data availability. To limit the influence of extreme outliers while preserving interpretability, unbounded continuous variables are winsorized at the 1st and 99th percentiles of the pooled distribution. Bounded indicators (e.g., 1–7 or 1–100 scales) and the ordered outcome CBDCAD are not winsorized. Missing WEF/GCR entries are handled with country-level linear interpolation between adjacent years; when a boundary year is missing, we carry the nearest observation forward/backward. The key variables are not imputed. These steps produce a tractable and transparent dataset aligned with the specifications reported in Tables 2–8. The retained 21 economies capture the main cross-country patterns relevant to our research question: they span multiple regions and income groups, cover the full support of CBDC stages observed in our window, and exhibit a wide dispersion in retail crypto adoption intensity (from near-zero to several hundred DAUs per million). This heterogeneity allows us to study how bottom-up retail crypto engagement co-moves with advancement along the CBDC lifecycle under diverse institutional environments, while maintaining consistent measurement across countries and years.

3.2. Key variables

The outcome is CBDC progression stage (denoted CBDCAD). We code CBDC progress as an ordered categorical variable: 0 = no official project, 1 = research/concept, 2 = pilot, 3 = live. Stages are taken from the Atlantic Council CBDC Tracker and mapped to the four-step lifecycle used in the paper. In our realized sample, observations span 0–3, with an overall mean of 1.33 (SD 0.77); Table 1 summarizes the distribution by country. CBDCAD is coded as an ordered policy-stage variable (no project, research, pilot, live) to reflect the sequential nature of CBDC programs. This coding is coarse and does not attempt to measure within-stage intensity (e.g., the size of a pilot or the depth of legal readiness), but it avoids imposing arbitrary cardinal distances across stages. Our baseline ordered-probit framework treats the outcome as ordinal and estimates threshold cutpoints. We also report fixed-effects OLS as a functional-form robustness check, with consistent results.

The main regressor is retail cryptocurrency adoption (denoted CRPTADP). We measure retail crypto activity as the average number of daily active users (DAUs) of cryptocurrency exchange apps per 1000,000 residents in a country–year. The underlying series is recently built from Sensor Tower usage data curated by Auer et al. (2025) and aggregates DAUs across 200 + identified crypto-exchange applications, with duplicate downloads excluded at source to avoid inflating participation counts. For each country, the raw high-frequency DAU streams are annualized by averaging across the calendar year and then population-normalized to “per-million inhabitants,” yielding a scale-free, cross-country comparable measure. Conceptually, CRPTADP captures active retail engagement with exchange platforms rather than mere app availability or cumulative downloads. It therefore tracks intensive-margin usage aligned with actual trading/interaction behavior. By construction, the metric emphasizes exchange-app activity and may understate off-exchange participation (e.g., self-custody wallet or DeFi usage). We interpret it as a behavior-based lower-bound proxy for retail engagement with crypto trading venues. To mitigate heavy tails without distorting bounded indices, CRPTADP is winsorized at the 1st/99th percentiles prior to estimation, and no imputation is applied. All steps, definitions, and the population normalization are harmonized to the paper’s annual panel (2019–2024) and country coverage).

Although CRPTADP is behavior-based (daily active use) rather than a stock measure (downloads), it remains a proxy for retail adoption centered on centralized exchange applications. It does not observe on-chain wallet activity (self-custody), decentralized finance (DeFi), or the intensity of transactions, so it may understate total participation and may include some browsing or login-only activity. Granular indicators of effective engagement such as daily active trading users are not publicly available in a consistent, country-resolved form across exchanges, and collecting them would require extensive platform-level data. Constructing a composite adoption index that integrates on-chain and off-chain metrics is therefore beyond the scope of this paper: consistent cross-country, retail-attributed on-chain activity series are largely proprietary and not publicly available for our full sample and horizon, and harmonizing multiple sources would require redesigning the paper's measurement strategy and re-matching the panel across outcomes, controls, and adoption series. In a small country-year panel, adding multiple closely related adoption proxies can also raise multicollinearity concerns and reduce statistical precision. We therefore interpret CRPTADP as a conservative lower-bound proxy for retail engagement with crypto trading venues and focus on robustness across specifications (lagged adoption, nonlinearities, influential-country exclusions, and IV/CMP identification).

Table 2
Summary statistics.

Variable	Count	Mean	SD	Min	P25	P50	P75	Max
CBDCAD	126	1.33	0.77	0.00	1.00	1.00	2.00	2.00
CRPTADP	126	71.74	82.42	0.04	22.54	45.58	92.08	408.02
GPR	126	86.07	26.21	58.42	64.07	79.03	89.49	138.67
MACRQLT	126	5.39	0.90	3.58	4.93	5.32	6.20	7.32
FINAFRD	126	4.59	0.87	2.72	3.76	4.73	5.35	6.02
FINAVLB	126	5.97	1.00	3.54	5.18	6.12	6.71	7.46
BNKSND	126	5.57	0.72	4.03	4.91	5.72	6.14	6.68
ENRGEF	126	73.32	18.32	26.46	63.06	76.79	89.44	95.53
LGFADP	126	4.48	0.69	3.10	4.03	4.57	4.85	6.09
LABPOL	126	4.22	0.93	2.57	3.03	4.57	5.09	5.30

Note: The table reports the summary statistics of the variables.

Table 3
Correlation matrix.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CBDCAD (1)	1									
CRPTADP (2)	0.03**	1								
GPR (3)	-0.13***	0.13***	1							
MACRQLT (4)	0.22***	0.18***	0.05**	1						
FINAFRD (5)	-0.33***	0.11***	0.07***	0.44***	1					
FINAVLB (6)	-0.41***	0.31***	0.05***	0.30***	0.31***	1				
BNKSND (7)	0.29***	0.14***	0.06***	0.27***	0.30***	0.37***	1			
ENRGEF (8)	0.27***	0.30***	0.04*	0.39***	0.32***	0.27***	0.33***	1		
LGFADP (9)	0.40***	0.25***	0.06***	0.41***	0.38***	0.37***	0.40***	0.45***	1	
LABPOL (10)	-0.34***	0.24***	0.04**	0.34***	0.36***	0.33***	0.38***	0.32***	0.34***	1
VIF	2.19									

Note: The table reports the pairwise correlations between variables and the VIF mean value.
* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$

Table 4
Baseline effects.

	(1)	(2)	(3)	(4)
CRPTADP	0.026***	0.040***	0.048***	0.056***
	(0.006)	(0.010)	(0.016)	(0.016)
MACRQLT		16.491***		17.109***
		(5.703)		(6.555)
FINAFRD		-17.309***		-17.082**
		(5.299)		(8.767)
FINAVLB		-30.905**		-34.827**
		(14.583)		(16.291)
GPR			-0.044*	-0.051**
			(0.023)	(0.022)
BNKSND			-16.181	18.157*
			(14.000)	(9.812)
ENRGEF			-0.003	1.838***
			(0.583)	(0.666)
LGFADP			6.030**	10.187*
			(2.560)	(5.667)
LABPOL			-1.974	-21.354**
			(25.000)	(9.517)
Pseudo R^2	0.605	0.629	0.631	0.650
Wald Chi^2	.	.	1019.901	.
Log likelihood	-23.751	-20.842	-20.583	-18.294
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	126	126	126	126

Notes. The Table reports the baseline effects of cryptocurrency adoption on CBDC adoption. Additional control variables include macroeconomic and institutional variables. The pool sample period is 2019–2024. We use an ordered probit model with country and year fixed effects and country-clustered standard errors. Model (1) includes only the key independent variable without controls. Model (2) includes the key independent variable with only financial controls. Model (3) includes the key independent variable with only non-financial controls. Model (4) includes the key independent variable with all controls. Definition of variables is provided in the Appendix.
* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$

3.3. Controls

We include a parsimonious set of macro-institutional covariates from WEF/GCR and GPR, motivated by the CBDC and digital-finance literatures. Unless noted, WEF/GCR indicators are country-level scores on bounded scales (either 1–7 or 1–100), measured annually; higher values generally denote more favorable conditions. Precise definitions and scales appear in Appendix 1.

The first control is geopolitical risk (GPR). Caldara and Iacoviello's (2022) monthly index, averaged to the year, proxies global and domestic tensions that can slow policy experimentation. We expect a negative association with CBDC progress (heightened risk → policy caution) (Wang and Gao, 2024). The second control is macroeconomic environment (MACRQLT, 1–7 best, WEF/GCR). Stronger macro frameworks can increase state capacity to run pilots and manage risks, suggesting a positive link to CBDC stage (Corbet et al., 2024; Davoodalhosseini et al., 2020). The third control is affordability of financial services (FINAFRD, 1–7 best, WEF/GCR). Where

Table 5
Endogeneity analysis.

	(1)	(2)	(3)	(4)
CRPTADP	0.010**	0.020***	0.015***	
	(0.006)	(0.001)	(0.001)	
GPR	-0.009*	-0.001*	-0.004*	
	(0.005)	(0.001)	(0.002)	
MACRQLT	0.191*	0.015*	2.926*	
	(0.239)	(0.028)	(2.489)	
FINAFRD	-0.997*	0.082	-0.793*	
	(0.844)	(0.081)	(4.642)	
FINAVLB	-0.353*	0.052*	-0.566*	
	(0.167)	(0.025)	(0.286)	
BNKSND	0.515	0.079*	-0.835	
	(0.576)	(0.038)	(4.143)	
ENRGEF	0.014*	0.011*	0.038	
	(0.007)	(0.006)	(0.087)	
LGFADP	1.155***	-0.289	5.093*	
	(0.394)	(0.254)	(2.547)	
LABPOL	-0.169*	-0.232*	-1.592*	
	(0.089)	(0.112)	(0.729)	
Treated				1.493***
				(0.027)
First stage				
INTDISR	-9.018***	-5.76***		
	(3.108)	(0.452)		
Kleibergen-Paap_F	16.665			
Second stage				
Pseudo R^2	0.689		0.648	0.657
F-stat	15.248		13.033	30.878
Kleibergen-Paap_LM (pv)	9.611*** (0.002)			
Atahrho (pv)		2.42 (0.273)		
Wald Chi^2	.	527.968		
Beta			0.012***	
Delta			1.035	
Mean bias (%)				9.605
N	126	125	126	125

Notes. The table reports the results of the endogeneity analysis. The outcome variable is CBDCAD. The key independent variable is CRPTADP. Additional control variables include macroeconomic and institutional variables. The pool sample period is 2019–2024. Model (1) uses an IV model with the 2SLS estimator. Model (2) uses an IV model with the CMP maximum likelihood estimator. The external instrument used in models (1) and (2) is the extent of internet disruptions in a country (INTDISR). Model (3) uses the Oster (2019) test of coefficient stability. Model (4) uses propensity score matching.
* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$

services are already affordable, the incremental policy need for a retail CBDC may be lower (potential negative association), though affordability also signals inclusion readiness (ambiguous net effect) (Ozili 2023a, 2023b; Corbet et al., 2024). The fourth control is availability of financial services (FINAVLB, 1–7 best, WEF/GCR). Broad service availability can either facilitate CBDC deployment (infrastructure readiness) or reduce urgency (substitution), so the sign is a priori ambiguous (Morales-Resendiz et al. 2021; Ozili 2023a, 2023b). The fifth control is soundness of banks (BNKSND, 1–7 best, WEF/GCR). More robust banking sectors might dampen policy urgency (concerns about disintermediation) or enable safer pilots via strong intermediation, ambiguous expected sign (Bindseil, 2020; Davoodalhosseini et al., 2020). The sixth control is energy-efficiency regulation (ENRGEF, 1–100, WEF/GCR). Clearer regulation is conducive to energy-efficient digital infrastructures, potentially supporting CBDC pilots (Agur et al., 2023; Dionysopoulos and Giaglis, 2022). The seventh control is legal adaptability to digital business (LGFADP, 1–7 best, WEF/GCR). Greater legal adaptability should facilitate experimentation and launch readiness (Dionysopoulos et al., 2024; Wang and Gao, 2024). The last control is active labor policies (LABPOL, 1–7 best, WEF/GCR). This policy-intensity proxy may correlate with capacity (positive) or competing priorities (negative); we regard the sign as ambiguous ex ante (Ozili 2023a, 2023b; Laboure et al., 2021).

We include additional controls in extended models. We consider: technological readiness (TECHRDN, 1–10, WEF/GCR) with expected positive effects (Hoang et al., 2023; Guo, Kreitem and Moser, 2024); fixed broadband subscriptions (INTERNT, 1–100, WEF/GCR) with expected positive effect (Morales-Resendiz et al. 2021; Lee et al., 2021); non-tariff barriers (NTRFBR, 1–7 highest, WEF/GCR), which could spur domestic digitalization (ambiguous) (Themistocleous et al., 2023; Wang and Gao, 2024); quality of infrastructure (INFRQLT, 1–100, WEF/GCR) with expected positive effect (Guo et al., 2024; Dionysopoulos and Giaglis, 2022); government adaptability (GVRADPT, 1–100, WEF/GCR) with expected positive effect (Maskaev et al., 2024; Ozili 2023a, 2023b); burden of regulation (GREGBR, 1–7 highest, WEF/GCR) with an expected negative (Conlon et al., 2022; Dionysopoulos et al., 2024); tax incentives to invest (TAXINV, 1–7 best, WEF/GCR), with often positive effect where investment incentives and regulatory clarity

Table 6
Sensitivity tests.

	(1)	(2)	(3)	(4)	(5)	(6)
QINDEX	-4.192**					
	(2.122)					
CRPTADP		0.005***	0.070**		0.055*	0.056***
		(0.001)	(0.031)		(0.031)	(0.016)
CRYPTSSQ			-0.003			
			(0.004)			
CRYPTSLG				0.013***		
				(0.005)		
GPR	-0.005***	-0.004	-0.053**	-0.034*	-0.032*	-0.051**
	(0.001)	(0.002)	(0.024)	(0.017)	(0.016)	(0.025)
MACRQLT	0.111	2.926	33.707***	33.402***	44.279***	27.113***
	(0.698)	(2.489)	(13.622)	(15.366)	(11.813)	(12.568)
FINAFRD	-2.206*	-0.793	-27.261**	-26.814***	-15.514	-27.083**
	(1.267)	(4.642)	(13.513)	(11.746)	(9.237)	(13.781)
FINAVLB	0.845	-0.566	-19.308**	-29.974**	-17.790***	-24.829**
	(0.969)	(3.266)	(9.447)	(12.568)	(7.451)	(12.299)
BNKSND	0.187	-0.835	14.754*	-27.795	11.084***	18.159*
	(0.774)	(4.143)	(7.450)	(20.941)	(4.901)	(9.820)
ENRGEF	-0.056*	0.038	1.757***	0.628*	2.922***	1.839***
	(0.033)	(0.087)	(0.647)	(0.364)	(1.275)	(0.666)
LGFADP	0.715	-5.093	12.821*	13.512***	14.317***	10.190*
	(1.350)	(4.047)	(6.875)	(6.907)	(7.048)	(5.683)
LABPOL	-1.046	-1.592	-14.584**	-24.761	-15.741***	-12.358**
	(1.223)	(4.529)	(7.713)	(14.449)	(7.074)	(6.532)
Adj. R^2		0.624				
Pseudo R^2	0.789		0.651	0.687	0.710	0.641
Wald Chi^2			.	1572.106	.	.
Log likelihood			-18.202	-16.933	-10.346	-18.294
F-test	22.595	13.033				
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	126	126	126	105	120	120

Notes. The table reports the effects after applying alternative variable measures and sample structures. The pool sample period is 2019–2024. We use ordered probit and OLS models with fixed effects. Model (1) uses an alternative measure of bitcoin adoption speed based on the Q index (QINDEX). Model (2) uses an alternative OLS model with fixed effects. Model (3) uses an additional squared value of the key regressor (CRYPTSSQ) to capture nonlinear effects. Model (4) uses a one-year lagged measure of the key regressor (CRYPTSLG) to capture lagged effects. Model (5) uses an alternative sample structure that excludes the country with the highest cryptocurrency adoption in the sample (Turkey). Model (6) uses an alternative sample structure that excludes the country with the lowest cryptocurrency adoption (China).

* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$

Table 7
Heterogeneity effects.

Variable	(1)	(2)
	Pr(CBDCAD>=1) (0→1)	Pr(CBDCAD=2) (1→2)
CRPTADP	0.0021***	0.0028***
	(0.0008)	(0.0008)
N	115	115

The table presents the marginal effects of changes in CRPTADP on each of the transition stages (0−1) and (1−2) of CBDCAD. Standard errors in parentheses.

* $p < 0.10$,
** $p < 0.05$,
*** $p < 0.01$

favor FinTech experimentation (Allen et al., 2022; Ozili 2023a, 2023b); and auditing/reporting standards (AUDREPR, 1–7 best, WEF/GCR) with expected positive effect via governance and accountability channels (Wang et al., 2022; Lee et al., 2021). Variable labels, scales, and sources match Appendix 1 and Tables 4–8.

3.4. Estimation model

We estimate ordered probit models with country and year fixed effects and country-clustered standard errors, consistent with the

Table 8
Additional control variables.

	(1)	(2)	(3)	(4)	(5)
CRPTADP	0.052***	0.054***	0.053***	0.053***	0.055***
	(0.014)	(0.016)	(0.017)	(0.016)	(0.018)
GPR	-0.051**	-0.051**	-0.053**	-0.050**	-0.052**
	(0.025)	(0.024)	(0.026)	(0.025)	(0.026)
MACRQLT	24.221***	22.770***	23.206	21.781***	27.248***
	(11.354)	(10.814)	(68.922)	(10.882)	(12.943)
FINAFRD	-21.100**	-13.596***	-18.898***	-18.266***	-12.919**
	(11.476)	(6.139)	(18.676)	(9.307)	(6.575)
FINAVLB	-31.593**	-13.434***	46.990	-17.083***	-14.479***
	(16.604)	(5.824)	(49.978)	(7.961)	(6.337)
BNKSND	7.216**	11.462***	-34.386	36.910***	47.670*
	(3.268)	(4.980)	(49.350)	(16.448)	(27.716)
ENRGEF	1.062	0.920	-4.958	0.267	0.615
	(0.799)	(0.786)	(3.095)	(0.729)	(0.712)
LGFADP	20.919***	24.172***	21.703***	23.133***	23.280***
	(8.844)	(10.593)	(10.763)	(9.445)	(11.744)
LABPOL	-24.846***	-23.501***	-27.267***	-28.577***	-17.685***
	(10.209)	(11.351)	(12.450)	(12.269)	(8.671)
TECHRDN	12.399**				
	(5.195)				
INTERNT		5.352**			
		(2.161)			
NTRFBR			5.658**		
			(2.605)		
INFRQLT				2.869***	
				(1.295)	
GVRADPT					2.459***
					(1.078)
Pseudo R^2	0.651	0.655	0.652	0.652	0.656
Log likelihood	-18.137	-18.128	-18.090	-18.054	-18.076
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	126	126	126	126	126

Notes. The Table reports the baseline effects of cryptocurrency adoption on CBDC adoption after adding control variables. The pool sample period is 2019–2024. We use an ordered probit model with fixed effects and country-clustered standard errors. Model (1) includes the additional effect of the extent of a country's technological readiness (TECHRDN). Model (2) includes the additional effect of fixed broadband subscriptions (INTERNT). Model (3) includes the additional effect of the prevalence of non-tariff barriers (NTRFBR). Model (4) includes the additional effect of the extent of secure infrastructure capacity (INFRQLT). Model (1) includes the additional effect of the extent of government adaptability (GVRADPT). Definition of variables is provided in the Appendix.

* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$

discrete, ordered nature of CBDCAD outcome and the panel structure of the data. Let $y_{it} \in \{0, 1, 2, 3\}$ denote the CBDC stage for country i in year t, with an underlying latent index:

$$\mathrm{CBDCAD}_{it} = \beta\ \mathrm{CRPTADP}_{it} + x_{it}'\gamma + \alpha_i + \tau_t + \varepsilon_{it},\ \varepsilon_{it} \sim N(0,1) \tag{1}$$

In our realized sample the support is 0–3, so three cutpoints are estimated. We include a full set of country dummies (α_i) to absorb time-invariant heterogeneity and year dummies (τ_t) to capture global shocks; vector x_{it} contains the controls. Estimation proceeds by maximum likelihood; we report log-likelihood, pseudo-R^2, and Wald χ^2 (where applicable), and we compute cluster-robust standard errors at the country level. All variables enter in levels on their original scales and winsorization (for CRPTADP and GPR) are applied pre-estimation as described in § 3.1. The full set of baseline and extended results is presented in Tables 4–10.

We model CBDC development as an ordered lifecycle and estimate an ordered probit to respect the ordinal information in CBDCAD. As in standard ordered-response models, this baseline specification imposes a "parallel regressions" (proportionality) restriction: slope coefficients enter the latent index identically across the estimated cutpoints. We emphasize, however, that this restriction does not imply identical probability effects across stage transitions. Because transition probabilities are nonlinear functions of the cutpoints and the latent index, the implied marginal effects can differ across thresholds and baseline stage probabilities. Substantively, we also recognize that CBDC transitions are not symmetric: entry into "research" is typically a lower-cost administrative choice, whereas progression from "research" to "pilot" (and beyond) is more feasibility-constrained and requires legal clarity, technical capacity, operational readiness, and reputational commitment. Accordingly, we interpret the coefficient on CRPTADP as shifting an economy's latent propensity to advance along the CBDC pipeline, while later-stage movement remains conditional on enabling factors: institutions, interactions, and heterogeneity.

4. Results

4.1. Descriptive analysis

The descriptive statistics in Table 2 show that the CBDC outcome (CBDCAD) is concentrated in the research and pilot phases over 2019–2024: the mean is 1.33 with a standard deviation of 0.77, and the observed support is 0–2. Due to luck of matched data the "live" countries are excluded. This distribution provides variation to study movement along the CBDC lifecycle while making clear that conclusions pertain to progression up to the pilot stage in this sample. Retail cryptocurrency adoption (CRPTADP) is skewed: the mean is 71.74 DAUs per million (SD 82.42), the median 45.58, with a long right tail reaching 408.02 (P25–P75: 22.54–92.08; minimum 0.04). These features justify the paper's light winsorization for unbounded variables and indicate that, absent controls, a few high-adoption episodes could dominate bivariate associations. The macro-institutional covariates span wide yet plausible ranges: GPR averages 86.07 (SD 26.21), MACRQLT (macroeconomic environment) 5.39 (SD 0.90), FINAVLB (availability) 5.97 (SD 1.00), and other WEF/GCR measures cluster on their bounded scales. This dispersion signals substantial cross-country differences in capacity and financial structure that can confound the raw link between crypto use and CBDC progress, underscoring the need for conditioning in multivariate analysis.

The correlation matrix (Table 3) clarifies why the unconditional association between CBDC progress and retail crypto use is small but significant (0.03**). CBDC stage correlates negatively with affordability (FINAFRD, −0.33***) and availability (FINAVLB, −0.41***) of financial services, suggesting lower policy urgency where traditional rails are already cheap and ubiquitous, while CRPTADP correlates positively with those same variables (FINAVLB, 0.31***; FINAFRD, 0.11***). These offsetting patterns naturally suppress the bivariate CBDCAD–CRPTADP correlation. At the same time, both CBDCAD and CRPTADP are positively related to state capacity proxies, MACRQLT (0.22*** and 0.18***) and LGFADP (0.40*** and 0.25***), respectively, implying potential positive confounding if such fundamentals are omitted. Geopolitical risk pulls in the opposite direction (−0.13***), which would bias downward the estimated effect of crypto adoption on CBDC progress if left uncontrolled. Reassuringly, multicollinearity is modest (mean VIF = 2.19), so these controls can be included jointly without destabilizing inference.

Table 2 and Table 3 imply that simple correlations understate the relationship of interest because financial-sector depth and geopolitical risk push CBDCAD and CRPTADP in opposite directions. This motivates the paper's ordered-probit strategy with rich controls and fixed effects: once we partial out these systematic forces, the positive association between retail crypto adoption and advancement along the CBDC lifecycle becomes visible and statistically precise in the multivariate results that follow.

4.2. Inferential analysis

Table 4 shows a clear and robust baseline association between retail crypto adoption and advancement along the CBDC lifecycle. Across the four baseline specifications, the coefficient on CRPTADP rises as controls are added: 0.026 (SE=0.006; $p < 0.01$ in column (1), 0.040 (SE=0.010; $p < 0.01$) with financial controls in column (2), 0.048 (SE=0.016; $p < 0.01$) with non-financial controls in column (3), and 0.056 (SE=0.016; $p < 0.01$) in the fully controlled model in column (4). Model fit improves in tandem (pseudo-R^2 from 0.605 to 0.650; log-likelihood from −23.751 to −18.294), with country and year fixed effects included throughout. These patterns indicate that, conditional on macro-institutional fundamentals and common shocks, higher retail crypto use is associated with a higher probability of being in a more advanced CBDC stage. The fact that the point estimate strengthens as controls are introduced is consistent with the suppression we documented in the descriptive/correlation analysis (financial-sector depth pushes CRPTADP and CBDCAD in opposite directions unconditionally).

The signs on controls are economically coherent and help explain the suppression in bivariate space. A stronger macroeconomic environment (MACRQLT) is positively associated with CBDC stage at 16.491 (SE=5.703; $p < 0.01$) in column (2) and 17.109 (SE=6.555; $p < 0.01$) in column (4), suggesting capacity facilitates progression. By contrast, affordability (FINAFRD) and availability (FINAVLB) of financial services are negative and significant: −17.309 (SE=5.299; $p < 0.01$) and −30.905 (SE=14.583; $p < 0.01$) in column (2); −17.082 (SE=8.767; $p < 0.5$) and −34.827 (SE=16.291; $p < 0.05$) in column (4). These coefficients imply that where traditional rails are already cheap and ubiquitous, the incremental policy impetus to move up the CBDC ladder is lower. Geopolitical risk (GPR) is negative and becomes statistically stronger as controls are added: −0.044 (SE=0.023; $p < 0.10$) in column (3) and −0.051 (SE=0.022; $p < 0.10$) in column (4), consistent with policy caution during tense periods. Among institutional enablers, legal adaptability (LGFADP) is positive: 6.030 (SE=2.560; $p < 0.05$) in column (3) and 10.187 (SE=5.667; $p < 0.10$) in column (4), while energy-efficiency regulation (ENRGEF) turns positive only in the full model (1.838, SE=0.666; $p < 0.01$). The sign on bank soundness (BNKSND) flips from negative and insignificant in column (3) to positive and marginal in column (4) (18.157, SE=9.812; $p < 0.10$), reflecting offsetting channels (capacity vs. disintermediation concerns). Together, the control patterns corroborate that the fully adjusted crypto coefficient is not proxying for general capacity or macro stability; it isolates the component of CBDC progress specifically associated with retail crypto use.

The baseline evidence supports the hypothesis that greater retail cryptocurrency adoption is associated with forward movement in CBDC projects. Because ordered-probit coefficients operate on a latent index, the precise probability effects depend on estimated thresholds. Nevertheless, the monotonic increase in CRPTADP's coefficient, its tight precision ($p < 0.01$ across all columns), and the improved fit once confounders are absorbed provide consistent evidence that retail crypto activity is a meaningful predictor of advancing from "no project" to "research", from "research" to "pilot" and from "pilot" to "launch" within the 2019–2024 window. This result remains firmly within-sample, so it speaks to progress up to the launch decisions. In short, after conditioning on macro-institutional fundamentals and common shocks, retail crypto adoption retains a substantive, statistically significant link to CBDC progression, aligning with the view that private digital-asset usage raises the salience, and potentially the urgency, of public digital-money initiatives.

5. Endogeneity

Endogeneity may arise because retail crypto use and CBDC progress could move together for reasons other than a causal effect, e.g., CBDC announcements may spur local crypto interest (reverse causality), omitted country fundamentals may shape both (omitted variables), and measurement error in app-use data can attenuate estimates. To probe causality, we deploy four complementary strategies: 2SLS estimation uses exogenous variation in crypto usage induced by internet disruptions (INTDISR) to identify the effect on CBDC staging; conditional mixed process (CMP) (Roodman, 2011) estimation estimates a full-information system that treats crypto adoption as endogenous within an ordered-response setting, allowing for correlated errors; Oster (2019) coefficient stability analysis gauges how strong selection on unobservables would need to be, relative to the rich observables already included, to wash out the effect; and propensity score matching compares "treated" high-adoption countries to matched controls after balancing observables to recover an ATT that is not tied to functional-form assumptions. Table 5 presents the results.

In the 2SLS method (Model 1), we address endogeneity between retail crypto use and CBDC progress, by instrumenting CRPTADP with the annual count of internet disruptions by country (denoted INTDISR), sourced from the StatCounter database. The relevance condition is strongly supported in the first stage: INTDISR is strongly negative and significant: −9.018*** (SE=3.108) in the 2SLS specification and −5.76* (SE=0.452) in the CMP specification, indicating that network disruptions materially reduce crypto-app activity, exactly as expected for a usage-based measure like DAUs. Cloudflare Radar disruption summaries (2024–2025) show 60–90% drops in national-level internet traffic during outages directly caused sharp falls in app activity. Reuters (2024) reported that West/Central Africa cable failures corroborated severe region-wide connectivity losses tracked by NetBlocks/Cloudflare. Internet Society / NetBlocks (COST) developed methodology to assess the impact of internet shutdowns on usage and economic activity. The Kleibergen–Paap F (16.665) exceeds conventional thresholds (>10) for weak-instrument concerns, and the significant Kleibergen–Paap LM test (9.611***, p <0.01) rejects under-identification. Together, these diagnostics confirm that INTDISR provides powerful exogenous variation in retail crypto adoption needed for identification.

The exclusion (exogeneity) condition is also plausible in this setting. CBDC stage changes are slow-moving policy decisions (no→research→pilot→launch) while internet disruptions are short-lived connectivity shocks that directly depress retail engagement with crypto apps but have no direct channel to CBDC staging beyond their effect on usage. Any residual pathways from disruptions to CBDC (e.g., broader unrest or policy bandwidth) are mitigated by: (i) country fixed effects that absorb time-invariant governance quality; (ii) year fixed effects that capture global shocks; and (iii) explicit controls for geopolitical risk and institutional capacity. Further, the CMP system's (Model 2) insignificant Atanh(ρ) (2.42, p > 0.10) does not reject the null of no cross-equation error correlation, providing an additional empirical check consistent with instrument exogeneity. While no instrument is perfect, these features and diagnostics make a compelling case that INTDISR affects CBDC staging primarily through retail crypto adoption.

Turning to the second stage, the IV estimates remain positive and significant. In 2SLS, the CRPTADP coefficient is 0.010 ($p < 0.05$); in the CMP ML system, it is 0.020 ($p < 0.01$); and in the Oster-based stability exercise (reported in the same table), the implied coefficient is 0.015 ($p < 0.01$). Magnitudes are smaller than the baseline ordered-probit coefficients, which is typical when IV corrects for attenuation from measurement error or for downward bias from confounders that raise crypto adoption while lowering CBDC propensity (e.g., geopolitical risk). Model fit remains high (reported pseudo-R^2 around 0.69–0.85 and F-statistics in the teens to low-30 s), and the sample sizes are essentially unchanged (N = 126 for 2SLS; N = 125 for CMP), indicating that the IV evidence is drawn from the same policy-relevant sample. The net message is that the crypto→CBDC link survives instrumented estimation and is unlikely to be spurious.

The Oster (2019) coefficient-stability test reinforces this conclusion (Model 3). The reported δ (Delta) = 1.035 indicates that unobservables would need to be about as strongly correlated with both the treatment and the outcome as the included observables to drive the estimated effect to zero, a robustness bar commonly viewed as non-trivial in applied work. The accompanying β = 0.012** suggests that, under plausible assumptions about the maximal attainable R^2, selection on unobservables of the same order of magnitude as observables would not overturn the core finding. In other words, once we account for the relatively rich controls already in the model, there is limited room for remaining confounders to eliminate the effect.

Complementing the IV evidence, the nearest-neighbor propensity-score matching (PSM) (Rosenbaum and Rubin, 1983) results display a large and precise difference in outcomes between treated and matched controls: defining treatment as the above-median CRPTADP, the treatment variable ATT = 1.493** (SE=0.027) indicates that countries with high retail crypto adoption exhibit CBDC stages roughly 1.5 levels higher than observationally similar countries with low adoption. Balance diagnostics confirm good match quality, with the mean bias reduced to 9.6%, below the 10% benchmark. Because CBDCAD takes values in {0,1,2,3} in this sample, this is a substantive shift along the outcome's support. While PSM relies on conditional independence given observables, the matching covariates here already include the macro-institutional and risk controls used throughout, so the PSM estimate is an informative non-parametric cross-check consistent with the regression and IV findings.

Across identification strategies (2SLS, CMP, Oster stability, and PSM) the evidence points in the same direction: retail cryptocurrency adoption is positively associated with advancing along the CBDC lifecycle, and this relationship is not an artifact of simple selection on observables or weak instrumentation. The IV magnitudes, if anything, provide a conservative local average treatment effect among countries whose crypto usage is sensitive to connectivity shocks, while the matching results emphasize the policy-relevant difference in CBDC staging between high- and low-adoption environments. Table 5 results substantively buttress the baseline conclusion that retail crypto uptake raises the likelihood that authorities move from "no project" to "research," from "research" to "pilot," and from "pilot" to "launch" within the 2019–2024 horizon.

We also note that our sample period (2019–2024) overlaps with the announcement of Libra (Diem) and the subsequent expansion of global stablecoins, an episode widely viewed as a catalyst for central-bank attention to digital currency competition and retail-payment sovereignty (G7 Working Group on Stablecoins, 2019; Brunnermeier et al., 2019; Bank for International Settlements, 2021, 2022). This raises the possibility of a "common third factor" that influences both retail crypto engagement and CBDC policy urgency. Our empirical design mitigates this in three ways. First, the inclusion of year fixed effects absorbs global, time-specific shifts in crypto-market attention and CBDC policy salience that are common across countries each year, including any broad wake-up call associated with BigTech entry into payments. Second, identification in our panel relies primarily on within-country changes relative to the global year effect: conditional on country fixed effects and controls, the coefficient on CRPTADP is driven by whether a country experiences larger or smaller increases in retail exchange-app activity than the global trend. Third, the positive association persists when we (i) use a one-year lag of CRPTADP, aligning with the sequencing of CBDC workstreams, and (ii) exploit idiosyncratic variation in retail usage induced by internet disruptions in IV/CMP frameworks, which is unlikely to be generated by a single global announcement.

We do not separately include a "Libra/Diem exposure" variable because there is no consistent, public, country-resolved series capturing Libra/Diem penetration or intensity over our horizon that can be matched to our annual CBDC-stage panel. Moreover, isolating a single episode of global policy attention would naturally call for a different design (e.g., a higher-frequency event-study with precisely dated CBDC milestone changes), which is beyond the scope of this paper. Accordingly, we interpret our estimates as capturing the relationship between observed retail crypto engagement, which reflects the intensity of private digital-asset participation during the stablecoin era, and progression along the CBDC policy pipeline, conditional on macro-institutional fundamentals and global shocks.

6. Robustness

6.1. Sensitivity analysis

The six checks in Table 6 probe whether the crypto–CBDC association is an artifact of model choice, functional form, timing, or influential observations. These tests confirm a stable, positive link between retail crypto adoption and advancement along the CBDC lifecycle within the observed support {0,1,2,3} over 2019–2024.

Model (1) uses an alternative key regressor, which is the Q-index (QINDEX), a country-level indicator of the timing/speed of Bitcoin adoption (learning) based on online attention: it is built from weekly Google Trends "Bitcoin" search indices (and Baidu for China, normalized), computing each country's search-intensity–weighted average week performance, so the index reflects how early vs. late search interest concentrates (Du et al., 2021). Lower Q values imply earlier, faster adoption-related attention, whilst higher Q values imply later, slower adoption. The approach follows the use of search data as an economic/adoption proxy (Choi and Varian, 2012). The coefficient on QINDEX is negative and statistically significant (−4.192**, SE = 2.122), indicating that faster Bitcoin adoption in a country is associated with stronger government incentives to advance to higher CBDC stages.

Model (2) applies an alternative linear OLS estimation benchmark. As a transparency check, we estimate a two-way fixed-effects OLS on the discrete outcome. The coefficient on CRPTADP is 0.005* (SE=0.001), with Adj. R^2= 0.624 and the expected signs on controls (e.g., MACRQLT positive; FINAVLB negative). Although OLS is not tailored to ordered outcomes, it is a standard robustness in FinTech/CBDC panels to verify sign consistency under a simpler link (e.g., linear-index comparisons in Corbet et al., 2024; Ozili 2023a, 2023b). The positive and precise estimate mirrors the ordered-probit results and suggests the baseline finding is not an artifact of the cumulative-link specification.

Model (3) tests for nonlinearity using a quadratic term. We augment the baseline ordered-probit with CRYPTSSQ = CRPTADP^2 to test for curvature such as diminishing returns/thresholds, which are often hypothesized in digital-adoption settings (Bolt et al., 2022; Auer et al., 2025). The linear term is 0.070 (SE=0.031; $p<0.05$) while the quadratic term is small and insignificant (−0.003, SE=0.004). Fit remains high (Pseudo-R^2=0.651). Hence, within observed ranges, the marginal association is approximately linear: higher retail crypto use continues to map into higher CBDC stages without clear evidence of saturation or threshold effects.

Model (4) tests for policy timing using a one-year lag value of the key regressor. Because the outcome (CBDCAD) is a slow-moving policy state variable (no project → research → pilot → live) that reflects multi-stage workstreams unfolding over time, and because CRPTADP is an annual average of daily activity, the contemporaneous specification should not be interpreted as an "instantaneous" policy reaction within the year. Rather, it captures whether retail adoption intensity co-moves with the policy state observed for that year. To align with the institutional reality that CBDC decisions follow exploration, consultation, and vendor workstreams, we lag the key regressor by one year (CRYPTSLG). The coefficient is 0.013** (SE=0.005) with Pseudo-R^2= 0.687 on N= 105 (reduced by lagging). This supports a reaction-lag channel of retail adoption in year $t-1$ is associated with advancing CBDC stage in year t - consistent with CBDC project timelines documented by central-bank case studies (Davoodalhosseini et al., 2020; Morales-Resendiz et al. 2021). The significance of the lag effect, together with our IV/CMP identification and additional endogeneity diagnostics, mitigates the concern that the baseline association is driven by contemporaneous feedback from CBDC progress to crypto-app usage.

Model (5) excluded the top-tail retail crypto adopter country (Turkey). Given the heavy-tailed distribution of retail adoption, we drop Turkey (the highest-adoption observation) to assess leverage. The CRPTADP coefficient remains positive and significant (0.055*, SE=0.031), with even stronger fit (Pseudo-R^2=0.710, N=120). Core controls retain expected signs (e.g., MACRQLT =44.279$***$, FINAVLB =−17.790$***$). This shows the association is not driven by a single extreme surge country, an important check given the adoption spikes highlighted in app-usage data (Auer et al., 2025).

Model (6) excludes the bottom-tail adopter country (China). Dropping China (the lowest-adoption observation) likewise leaves the result intact: CRPTADP = 0.056** (SE=0.016), Pseudo-R^2= 0.641, N= 120. As in the baseline, stronger macro capacity (MACRQLT) and legal adaptability (LGFADP) are positive, while affordability/availability (FINAFRD, FINAVLB) load negatively, which is consistent with the interpretation that robust existing rails reduce policy urgency for a retail CBDC. The persistence of a large, precise CRPTADP coefficient under both top- and bottom-tail exclusions demonstrates outlier-robustness of the main finding.

Overall, across alternative, linear and ordered links, functional-form enrichment, policy-relevant lags, and influential-case exclusions, the sign and significance of the retail-adoption coefficient do not flip and remain economically meaningful. Combined with the literature that emphasizes sequencing and capacity in CBDC programs (Davoodalhosseini et al., 2020; Morales-Resendiz et al. 2021; Bolt et al., 2022), these sensitivities reinforce the conclusion that greater retail cryptocurrency adoption is associated with movement up the CBDC ladder from no project to research and from research to pilot in 2019–2024, not a by-product of model choice or leverage by a few observations.

6.2. Heterogeneity analysis

CBDC stage changes are substantively asymmetric. Moving from “no project” (Stage 0) to “research” (Stage 1) is typically a relatively low-cost administrative step, whereas moving from “research” (Stage 1) to “pilot” (Stage 2) and beyond generally requires stronger legal and operational readiness, dedicated technical resources, and greater reputational commitment. To assess whether retail crypto adoption (CRPTADP) is more closely associated with early-stage entry or with more resource-intensive advancement, we compute threshold-specific (cumulative) marginal effects from the ordered-probit model for (i) crossing the first threshold, Pr(CBDCAD $\geq$ 1), and (ii) crossing the second threshold, Pr(CBDCAD $\geq$ 2). Table 7 reports these average marginal effects. The estimates indicate that higher CRPTADP increases the probability of being at least in the research stage (AME = 0.0021***) and has an even larger association with reaching the pilot-or-live stages (AME = 0.0028***). While we do not claim that these differences represent separate transition coefficients, the pattern of marginal effects suggests that retail crypto adoption is not merely associated with low-cost exploratory moves; it is also associated, at least as strongly, with progression into stages that require tangible implementation capacity. This strengthens the paper’s answer to the research question by indicating that retail crypto adoption correlates with advancement along the CBDC pipeline, not only with initial policy salience.

6.3. Additional controls

Table 8 augments the fully specified ordered-probit with five conceptually distinct additional controls that capture digital readiness, connectivity, trade frictions, infrastructure security, and government adaptability. Across all columns, the crypto-adoption coefficient remains positive and tightly estimated, between 0.052* and 0.055*, and model fit is virtually unchanged (Pseudo-R^2 about 0.651–0.656), indicating that the baseline association is not an artifact of omitted digital-capacity covariates. Core controls keep the expected signs (GPR negative; MACRQLT positive; FINAFRD/FINAVLB negative), providing additional internal coherence.

Model (1) adds technological readiness (TECHRDN). Adding technological readiness (1–10) yields TECHRDN = 12.399 (SE=5.195; $p < 0.05$) and leaves CRPTADP materially unchanged at 0.052* (SE=0.014). This is consistent with the idea that broader ICT capability facilitates policy experimentation and implementation of complex payment innovations (e.g., CBDC pilots), but the crypto–CBDC link remains strong even after conditioning on tech readiness (Hoang et al., 2023; Guo et al., 2024). GPR stays negative (−0.051*) and MACRQLT positive (24.221*), while affordability/availability remain negative, reinforcing our earlier “lower urgency where rails are already good” interpretation. Pseudo-R^2 = 0.651; N = 126.

Model (2) adds fixed broadband subscriptions (INTERNT). INTERNT measures fixed broadband (1–100). It enters positively (5.352; SE=2.161; $p < 0.05$), aligning with evidence that broadband density supports both digital-payments adoption and public digital-money rollouts through lower access frictions and better last-mile reliability (Morales-Resendiz et al. 2021; Lee et al., 2021). The CRPTADP coefficient is 0.054* (SE=0.016), essentially identical to Model (1), signaling that the crypto effect is not proxying for broadband connectivity. Fit inches up (Pseudo-R^2 = 0.655).

Model (3) adds non-tariff barriers (NTRFBR). Adding prevalence of non-tariff barriers (1–7 highest) produces a positive association (NTRFBR = 5.658; SE=2.605; $p < 0.05$). One interpretation is that tighter trade frictions can increase incentives to domesticate digital-finance infrastructure, including CBDCs, to improve resilience and control (Themistocleous et al., 2023; Wang and Gao, 2024). Some coefficients become imprecise (e.g., FINAVLB = 46.990, SE=49.978), but CRPTADP remains 0.053* (SE=0.017) and GPR stays negative (−0.053), preserving the core message. Pseudo-R^2 = 0.652.

Model (4) adds secure infrastructure capacity (INFRQLT). Introducing quality/secure infrastructure (1–100) yields a precise positive effect (2.869*; SE=1.295), consistent with the notion that robust, secure infrastructure is a precondition for CBDC pilots and integration with national rails (Guo et al., 2024; Dionysopoulos and Giaglis, 2022). The CRPTADP coefficient is 0.053* (SE=0.016); BNKSND (bank soundness) turns strongly positive (36.910*), suggesting capacity and safety nets co-move with CBDC progression once infrastructure quality is held constant. Pseudo-R^2 = 0.652.

Model (5) adds government adaptability (GVRADPT). Adding government adaptability (1–100) produces a positive, significant coefficient (2.459*; SE=1.078), echoing findings that agile public administrations move faster on regulatory design, vendor management, and legal/policy adaptations required by CBDCs (Ozili 2023a, 2023b; Maskaev et al., 2024). The crypto-adoption effect is again stable (0.055*; SE=0.018), while MACRQLT and LGFADP remain positive and FINAFRD/FINAVLB remain negative, painting a consistent picture of policy capacity and legal adaptability enabling advancement even as strong legacy rails reduce urgency. Pseudo-R^2 = 0.656; LogL = −18.076.

Overall, the stability of CRPTADP (0.052–0.055, $p < 0.01$) across all five enriched specifications means the positive association between retail crypto adoption and CBDC progress is not attributable to omitted dimensions of digital readiness, connectivity, trade frictions, infrastructure security, or public-sector agility. Instead, even after conditioning on these new controls, each supported by the CBDC design and digital-finance literatures, the data continue to indicate that higher retail crypto engagement is associated with movement up the CBDC ladder over 2019–2024.

6.4. Dominance analysis

Table 9 decomposes model fit into relative importance weights ("dominance" shares) for each regressor (Azen and Budescu, 2003). Within each subsample the weights sum to the reported Fit-stat, so a larger weight means the variable explains a larger portion of the outcome's variance after averaging over all model subsets. Importantly, dominance speaks to contribution to fit, not the sign of the coefficient. A covariate can contribute a lot to explanatory power even if its estimated sign is negative.

Model (1) uses the full sample (N = 126, Fit-stat=0.360). The single largest contributor to explained variation in CBDCAD is active labor policies (LABPOL) with a dominance weight of 0.1255, about 34.9% of total fit, followed by affordability (FINAFRD, 0.0474 → 13.2%), legal adaptability (LGFADP, 0.0463 → 12.9%), availability (FINAVLB, 0.0422 → 11.7%), and bank soundness (BNKSND, 0.0408 → 11.3%). By contrast, CRPTADP accounts for 0.0056 (1.6%) and GPR for 0.0089 (2.5%). Two implications follow. First, institutional capacity and the structure of legacy rails explain a large share of cross-country differences in CBDC stage, which is consistent with the literature that highlights policy capability, legal readiness, and existing financial access as central preconditions for CBDC progress (e.g., Corbet et al., 2024; Ozili 2023a, 2023b; Morales-Resendiz et al. 2021). Second, the relatively small full-sample share for CRPTADP is not at odds with its positive and significant baseline coefficient. It simply says that the background institutional environment contributes more to overall fit than any single behavioral driver when all 21 economies are pooled.

Model (2) uses developed economies only (N = 90, Fit-stat=0.388). The pattern persists and sharpens in the developed-only subsample. LABPOL remains the top contributor (0.1233 → 31.8%), while FINAFRD (0.0546 → 14.1%), LGFADP (0.0516 → 13.3%), FINAVLB (0.0482 → 12.4%), and MACRQLT (0.0433 → 11.2%) occupy the next tier. CRPTADP contributes 0.0075 (1.9%). This tells us that, among advanced systems, CBDC progression is dominated by policy/administrative intensity, legal adaptability, and mature financial rails, with retail crypto activity playing a secondary (but still positive) role, exactly the narrative in which strong legacy affordability/availability can reduce policy urgency for retail CBDCs even as they provide capacity to run pilots (e.g., Bindseil, 2020; Ozili 2023a, 2023b; Davoodalhosseini et al., 2020). The slightly higher fit (0.388 vs 0.360) underscores how much of the variation in CBDC stage within developed economies is captured by institutional fundamentals rather than behavioral adoption alone.

Model (3) uses developing economies only (N = 36, Fit-stat=0.420). The picture changes meaningfully in the developing-economy subsample. Here, energy-efficiency regulation (ENRGEF) tops the list (0.0634 → 15.1%), with macro environment (MACRQLT, 0.0614 → 14.6%), availability (FINAVLB, 0.0603 → 14.4%), and active labor policies (LABPOL, 0.0595 → 14.2%) clustered close behind. Crucially, CRPTADP's dominance weight jumps to 0.0395, about 9.4% of fit, five to six times its share in the developed sample, while GPR is negligible (0.0053 → 1.3%). This pattern aligns with the idea that in EMDEs, both "hard" capacity (infrastructure, energy-efficiency standards) and "soft" capacity (policy intensity) are key, and retail crypto uptake becomes a material driver of CBDC progress once those enabling conditions are present. The prominence of ENRGEF dovetails with evidence that energy-efficient, reliable infrastructure is a practical prerequisite for retail CBDC pilots and operations (Agur et al., 2023; Dionysopoulos and Giaglis, 2022), while the elevated importance of CRPTADP resonates with case-study accounts of bottom-up digital adoption nudging policymakers in emerging settings (Corbet et al., 2024; Morales-Resendiz et al. 2021). The highest fit (0.420) in this subsample indicates the model explains more of the observed variation in CBDC stages among developing countries than elsewhere.

Table 9
Dominance analysis.

	(1)	(2)	(3)
CRPTADP	0.0056	0.0075	0.0395
GPR	0.0089	0.0111	0.0053
MACRQLT	0.0331	0.0433	0.0614
FINAFRD	0.0474	0.0546	0.0381
FINAVLB	0.0422	0.0482	0.0603
BNKSND	0.0408	0.0349	0.0484
ENRGEF	0.0098	0.0130	0.0634
LGFADP	0.0463	0.0516	0.0440
LABPOL	0.1255	0.1233	0.0595
Fit-stat	0.360	0.388	0.420
N	126	90	36

Notes. The table reports the dominance effects of all regressors on CBDCAD across different development levels. The pool sample period is 2019–2024. Model (1) shows the dominant effect of each regressor on CBDCAD across the whole sample. Model (2) shows the dominant effect of each regressor on CBDCAD for developed countries only. Model (3) shows the dominant effect of each regressor on CBDCAD for developing countries only.
* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$

Dominance results refine the main regression evidence. In the full and developed samples, institutional fundamentals (policy intensity, legal adaptability, financial-services structure) account for the largest shares of explained variation in CBDC stage, with retail crypto adoption adding a smaller but positive piece. In developing economies, by contrast, retail adoption's relative importance rises sharply (9–10% of fit), approaching the contribution of core capacity variables. This is consistent with the paper's heterogeneity narrative and with the broader literature that emphasizes the joint roles of adoption pressure and state capacity in CBDC progression. In short, CRPTADP is a meaningful predictor, especially in EMDEs, but CBDC progress is ultimately embedded in a broader capacity and governance context, as the dominance weights make clear.

The results suggest that the crypto–CBDC relationship is not uniform across development levels, which helps explain why descriptive global surveys can mask heterogeneous policy dynamics. In the developed-economy subsample, CBDC progression is dominated by institutional fundamentals and legacy-rail characteristics, while retail crypto adoption contributes relatively little to explained variation. In contrast, in the developing-economy subsample, retail crypto adoption accounts for a materially larger share of explained variation in CBDC stage, consistent with the idea that in EMDEs retail adoption is more likely to be tied to payment frictions, remittance demand, and currency-competition pressures (Corbet et al., 2024; Ozili 2023a, 2023b; Laboure et al., 2021). Moreover, political-economy and governance constraints systematically condition responsiveness to retail signals: high regulatory burden and certain tax environments attenuate the adoption-to-CBDC link, whereas stronger auditing/reporting standards amplify it. These patterns add a mechanism-consistent interpretation to the cross-country variation in CBDC progress and highlight that "private adoption pressure" interacts with state capacity rather than operating as a universal trigger.

7. Enhancement channels

Table 10 augments the baseline ordered-probit with interaction terms that test whether the crypto-to-CBDC association varies with three institutional features: regulatory burden (GREGBR), tax incentives to invest (TAXINV), and auditing/reporting standards (AUDREPR). All columns include country and year fixed effects and the same control block as in earlier tables; fit remains high (Pseudo-R^2=0.651–0.663; $N = 126$). Below we interpret each specification and connect the patterns to the literature cited in the paper.

Model (1) explores the role of the burden of regulation (GREGBR). The main effect of retail crypto adoption is positive and large (CRPTADP=0.321**, SE=0.103), while the interaction CRPTADP × GREGBR is negative and significant (−0.065**, SE=0.023), with Pseudo-R^2= 0.663. Because GREGBR is scaled 1–7 (higher=heavier burden), the marginal slope of crypto adoption on the CBDC latent index is $0.321 - 0.065 \times$GREGBR. The turning point is about$0.321/0.065 \simeq 4.94$: for regulatory burdens below 5, greater retail crypto use is associated with more CBDC progress; at the very high end (6–7), the slope becomes weak or negative. This attenuation is consistent with the idea that procedural frictions and compliance costs slow experimentation and policy translation from market signals (e.g., pilot design, legal reviews), thereby muting the response to retail adoption (Conlon et al., 2022; Dionysopoulos et al., 2024). In short, lower regulatory burden amplifies the crypto-to-CBDC link, whilst heavy regulation dampens it.

Model (2) explores the role of tax incentives to invest (TAXINV). The main crypto coefficient remains positive and precise (CRPTADP=0.210**, SE=0.079), while the interaction CRPTADP × TAXINV is negative and significant (−0.035**, SE=0.016), with Pseudo-R^2= 0.660. Given the 1–7 (higher=more investment-friendly) scale, the marginal slope is $0.210 - 0.035 \times$TAXINV. The break-even is exactly 6.0: for TAXINV$<$ 6 the crypto effect is positive, but at very investment-friendly tax regimes (≥6–7) the marginal association weakens and can turn slightly negative. One interpretation is that when private investment conditions are already highly supportive, authorities feel less urgency to accelerate a CBDC in response to retail crypto activity. Conversely, where tax disincentives are stronger (lower TAXINV), retail adoption may act as a sharper policy signal to upgrade public digital money rails (Allen et al., 2022; Ozili 2023a, 2023b). The key takeaway is attenuation, not reversal: the interaction shows where the crypto-CBDC link is strongest (moderate-to-low investment incentives) versus muted (very high incentives).

Model (3) explores the role of auditing and reporting standards (AUDREPR). Here the interaction CRPTADP × AUDREPR is positive and significant (+0.018**, $p < 0.05$), while the main crypto term is smaller and not significant (0.098, SE=0.067); Pseudo-R^2= 0.651. With AUDREPR on a 1–7 (higher=stronger standards) scale, the marginal slope is $0.098 + 0.018 \times$AUDREPR. At mid-sample values (4–5), the implied slope is about 0.17–0.19 on the latent index, indicating that stronger auditing/reporting materially amplifies how retail crypto adoption translates into policy progression. This pattern matches arguments that governance, transparency, and assurance functions (e.g., supervisory analytics, auditability of platforms, institutional learning from DCEP/e-CNY) lower perceived risks and enable authorities to act on market signals more decisively (Wang et al., 2022; Lee et al., 2021). In other words, the capacity to measure and monitor digital finance strengthens the crypto-to-CBDC channel.

Overall, the moderation results refine the baseline conclusion: retail crypto adoption is positively associated with CBDC advancement, especially where policy frictions are low, tax environments are not excessively investment-friendly (hence crypto signals bite), and governance/assurance systems are strong. These patterns are aligned with the CBDC design and digital-finance literatures that emphasize the joint roles of institutional capacity and regulatory environment in moving from no project to research and pilot (e.g., Davoodalhosseini et al., 2020; Morales-Resendiz et al. 2021; Ozili 2023a, 2023b).

8. Conclusions

Whether bottom-up retail engagement with cryptocurrencies nudges authorities to advance Central Bank Digital Currencies (CBDCs) is central to current debates on the future of public money. The question matters for macro-stability, payments competition, and financial inclusion: if private digital adoption raises the salience or urgency of a public digital option, policymakers need early

Table 10
Enhancement channels.

	(1)	(2)	(3)
CRPTADP	0.321***	0.210***	0.098
	(0.103)	(0.079)	(0.067)
CRPTADP * GREGBR	-0.065***		
	(0.023)		
CRPTADP * TAXINV		-0.035**	
		(0.016)	
CRPTADP * AUDREPR			0.018**
			(0.009)
Controls	Yes	Yes	Yes
Pseudo R^2	0.663	0.660	0.651
Log likelihood	-16.671	-17.063	-18.175
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	126	126	126

Notes. The table reports the effect of moderating factors on the association between cryptocurrency adoption and CBDC adoption. We use an ordered probit model with fixed effects and country-clustered standard errors. Model (1) presents the moderating effect of the burden of government regulation (GREGBR). Model (2) presents the moderating effect of taxation on the incentive to invest (TAXINV). Column (3) presents the moderating effect of the strength of accounting and auditing standards (WEF271). Definition of variables is provided in the Appendix.
* $p < 0.1$,
** $p < 0.05$,
*** $p < 0.01$.

warning indicators and diagnostic benchmarks. This paper brings together a behavior-based, cross-country measure of retail crypto use (app daily active users) and a staged measure of CBDC progress to examine that link across 21 economies, 2019–2024 in a balanced panel. By aligning high-frequency adoption data with the widely used Atlantic Council CBDC lifecycle and estimating ordered-response models with rich institutional controls, the study speaks directly to whether retail crypto activity is a meaningful predictor of movement up the CBDC ladder from “no project” to “research” to “pilot” to “launch.”

The baseline ordered-probit estimates show a positive and statistically precise association between retail crypto adoption and CBDC stage that strengthens as controls are added. Additional controls for technological readiness, broadband, non-tariff barriers, infrastructure quality, and government adaptability leave the crypto coefficient essentially unchanged, indicating the link is not an artifact of omitted digital-capacity variables. Sensitivity checks confirm robustness to functional/linear form, timing, and influential observations. Endogeneity tests reinforce the message: instrumenting crypto adoption with internet disruptions yields significant positive effects, with strong first-stage diagnostics and no evidence of cross-equation error correlation. The Oster stability metric suggests selection on unobservables would need to rival selection on observables to nullify the effect, and propensity-score matching indicates a large, policy-salient difference between high- and low-adoption countries. Dominance results clarify that institutional fundamentals explain most cross-country variation in CBDC stage in the pooled and advanced-economy samples, but retail adoption’s relative importance rises sharply in developing economies. Moderation tests show heavier regulatory burdens and more investment-friendly tax regimes attenuate the crypto-CBDC link, whereas strong auditing/reporting standards amplify it. These results consistently indicate that higher retail crypto adoption is associated with progress from no project to research and from research to pilot within the study window.

The results carry policy implications. First, signal extraction: behavior-based crypto-adoption metrics can serve as timely indicators of policy pressure for CBDC workstreams. Authorities could monitor retail app use alongside traditional diagnostics (payments frictions, inclusion gaps) to anticipate when to accelerate consultations, proofs-of-concept, or pilots. Second, capacity prerequisites: the dominance and moderation results highlight that macro/legal capacity and governance quality condition how strongly retail signals translate into CBDC progress. Investments in legal adaptability, secure infrastructure, auditing/reporting standards, and state capability appear complementary to CBDC advancement. Heavy procedural burdens can blunt responsiveness to market signals. Third, sequencing: the positive lagged association is consistent with policy reaction times, suggesting that central banks may plan resource allocation over multi-year horizons when retail adoption surges. Fourth, targeting: since the relative importance of retail adoption is higher in EMDEs, capacity building and regulatory streamlining in those jurisdictions may yield the greatest policy traction when retail crypto activity rises. These implications speak to practical levers, i.e., governance upgrades, regulatory simplification where appropriate, and better data infrastructure, that can help authorities calibrate CBDC roadmaps in response to evolving private-sector adoption.

Our results should not be read as implying that CBDC acceleration is the universally “correct” response to rising retail crypto activity. Rather, behavior-based adoption measures can serve as diagnostic early-warning indicators that retail digital-asset engagement is intensifying, prompting authorities to choose among a policy toolkit: targeted prudential and conduct regulation, AML/CFT supervision and enforcement, consumer-protection interventions, and, where consistent with mandate and feasibility, CBDC experimentation. The appropriate mix depends on whether adoption is dominated by payment utility versus speculative or integrity-risk motives. Because our adoption proxy does not decompose these motives, we treat motive composition as a scope condition and an avenue for future research using motive-resolving datasets to test whether the adoption–CBDC association is stronger when usage is payments-oriented or speculative.

The analysis is intentionally conservative. The panel covers 21 economies and 2019–2024, a period in which the outcome's realized support is 0–3. The retail adoption proxy captures exchange-app DAUs and may not fully reflect self-custody wallets, DeFi usage, or off-platform activity; measurement error likely biases against finding effects and is one reason the IV estimates are somewhat smaller than baseline coefficients. CBDC stages are annualized from event-driven updates and abstract from within-year dynamics. The ordered-response framework imposes proportional-odds structure, which we partially address with robustness checks but do not exhaustively relax. Finally, the instrument (internet disruptions) is credible and statistically strong, but like any instrument could be questioned if there are unobserved channels from connectivity shocks to policy bandwidth; extensive controls and fixed effects mitigate (but cannot eliminate) this concern. These caveats bound the scope of inference and point to several constructive extensions.

Three avenues are especially promising. First, longer horizons and broader coverage that include "live" CBDC launches would allow explicit analysis of the transition to stage 3, ideally in a transition-hazard framework at monthly frequency to exploit the timing of stage changes and retail-adoption shocks. Second, richer adoption measures, combining app DAUs with on-chain user counts, fiat on-ramp volumes, stablecoin flows, and survey microdata, could sharpen identification and mechanism tests (e.g., inclusion vs. speculation vs. capital-flight hedging). Third, design and governance channels deserve deeper study: how does privacy/auditability, interoperability, and public–private partitioning of the tech stack mediate the crypto-to-CBDC link; how do regulatory or tax reforms alter the marginal effect of retail adoption; and what role do cross-border considerations play in shaping domestic CBDC timelines? Extending the analysis along these lines would probe whether the causal pathways suggested here are durable as more countries progress to pilots and launches.

In sum, the study documents a robust, policy-relevant association between retail cryptocurrency adoption and advancement of CBDC projects up to the pilot stage. The strength and consistency of the estimates across identification strategies, sensitivity checks, and enriched specifications, together with the clear role of institutional capacity and governance, suggest that private digital adoption is an informative leading indicator of public digital-money progress, especially where states have the capacity to act.

CRediT authorship contribution statement

Charilaos Mertzanis: Writing – review & editing, Supervision, Software, Investigation. **Thabet Bakheet Thabet:** Writing – original draft, Methodology, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare no known conflicts of interest in carrying out this research.

Appendix 1. Definition of variables

Variable	Definition	Source
CBDCAD	Retail CBDC stage (ordered): 0 = no official project; 1 = research/concept; 2 = pilot (live, limited trials); 3 = live (launched). Annualized from the Atlantic Council tracker.	Atlantic Council CBDC Tracker
CRPTADP	Retail crypto adoption: average daily active users (DAUs) of cryptocurrency exchange apps per 1000,000 residents; aggregates 200 + apps; duplicate downloads excluded; annualized from Sensor Tower usage data.	Auer et al. (2025), BIS/IMF dataset (Sensor Tower)
GPR	Geopolitical Risk Index: annual average of the Caldara–Iacoviello index capturing geopolitical tensions and policy uncertainty.	Caldara and Iacoviello (2022)
MACRQLT	Macroeconomic environment quality (WEF/GCR score, 1–7; higher = better).	World Economic Forum — Global Competitiveness Report (WEF/GCR)
FINAFRD	Affordability of financial services (WEF/GCR score, 1–7; higher = more affordable).	WEF/GCR
FINAVLB	Availability/breadth of financial services (WEF/GCR score, 1–7; higher = greater availability).	WEF/GCR
BNKSND	Soundness and stability of banks (WEF/GCR score, 1–7; higher = more sound).	WEF/GCR
ENRGEF	Energy-efficiency regulation supporting digital infrastructure (WEF/GCR score, 1–100; higher = stronger regulation).	WEF/GCR
LGFADP	Legal framework's adaptability to digital business models (WEF/GCR score, 1–7; higher = more adaptable).	WEF/GCR
LABPOL	Active labor-market policies (WEF/GCR score, 1–7; higher = stronger policies).	WEF/GCR
TECHRDN	Technological readiness and adoption capacity (WEF/GCR score, 1–10; higher = greater readiness).	WEF/GCR
INTERNT	Fixed broadband internet subscriptions (WEF/GCR normalized score, 1–100; higher = greater penetration).	WEF/GCR
NTRFBR	Prevalence of non-tariff barriers to trade (WEF/GCR score, 1–7; higher = more barriers).	WEF/GCR
INFRQLT	Quality and security of infrastructure for digital connectivity (WEF/GCR score, 1–100; higher = better).	WEF/GCR
GVRADPT	Government adaptability/agility to new technologies (WEF/GCR score, 1–100; higher = more adaptable).	WEF/GCR
GREGBR	Burden of government regulation (WEF/GCR score, 1–7; higher = heavier burden).	WEF/GCR
TAXINV	Effect of taxation on incentives to invest (WEF/GCR score, 1–7; higher = stronger incentives).	WEF/GCR

(*continued on next page*)

(*continued*)

Variable	Definition	Source
AUDREPR	Strength of accounting, auditing, and reporting standards (WEF/GCR score, 1–7; higher = stronger standards).	WEF/GCR
INTDISR	Internet disruptions per country–year; used as an external instrument (IV) for retail crypto usage in IV/CMP specifications.	StatCounter GlobalStats (https://gs.statcounter.com/)

Data Availability

Data will be made available on request.

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