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Central Bank Digital Currencies and Bank Deposit Dynamics: Evidence from Cross-Country Difference-in-Differences Analysis

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Abstract: The emergence of central bank digital currencies (CBDCs) represents one of the most significant innovations in contemporary monetary systems. As central banks explore digital forms of sovereign money, an important question concerns how CBDC introduction may affect the structure of financial intermediation, particularly the role of commercial bank deposits. Because CBDCs constitute a direct claim on the central bank, their availability may alter the allocation of liquid assets held by households and firms and potentially influence bank funding structures.

Theoretical research emphasizes that the macro-financial implications of CBDCs depend critically on their design features, including remuneration policies, holding limits, access rules, and distribution models. These design parameters determine the relative attractiveness of CBDCs compared with traditional bank deposits and therefore shape the magnitude of potential deposit substitution. However, empirical evidence on the real-world effects of CBDC implementation remains limited due to the recent emergence of CBDC projects and the substantial heterogeneity in their design and operational frameworks across countries.

This paper investigates whether the activation of a CBDC is associated with changes in commercial bank deposit holdings using a cross-country panel dataset covering 30 economies over the period 2015–2024. The empirical analysis employs a Difference-in-Differences framework with staggered treatment timing, complemented by event-study estimates and alternative estimators designed to address identification challenges in two-way fixed-effects models. To partially capture cross-country heterogeneity related to CBDC design and adoption environments, the specification incorporates interaction terms reflecting differences in financial digitalization and payment system structure.

The results indicate that CBDC activation is associated with a statistically significant decline in bank deposits as a share of GDP, with stronger effects observed in digitally advanced financial systems.

Keywords: central bank digital currency, bank deposits, financial intermediation, Difference-in-Differences.

JEL Classification: E42, E58, F31.

1. Introduction

Central bank digital currencies (CBDCs) have rapidly moved from a conceptual discussion within academic and policy circles to an active component of monetary innovation worldwide. As digitalization reshapes financial systems and alters the ways in which households, firms, and governments interact with money, central banks have been increasingly exploring the opportunities and risks associated with issuing their own digital currencies. While CBDCs promise greater efficiency, financial inclusion, and resilience of payment infrastructures, they also raise important concerns about bank disintermediation, financial stability, and the transmission of monetary policy.

The growing body of theoretical and empirical research highlights that the introduction of a CBDC could significantly reshape the structure of the financial system by altering the role of commercial banks, shifting the composition of money holdings, and modifying the competitive landscape between private and public forms of money. At the same time, global experimentation with CBDCs from pilot programs in China and the Eastern Caribbean to full implementation in the Bahamas demonstrates the diverse motivations and design choices shaping CBDC development across jurisdictions.

Given the ongoing international debate and the absence of consensus regarding the precise implications of CBDC introduction, it is essential to assess how such innovations affect key components of the financial system, particularly bank deposits, which remain a foundational source of liquidity and funding for commercial banks. This paper contributes to this discussion by combining a detailed theoretical examination of CBDC design and functionality with an econometric investigation of how CBDC activation influences bank deposit levels. Using a panel of 30 countries from 2015 to 2024 and applying both Difference-in-Differences and event-study approaches, the analysis provides new evidence on the magnitude and dynamics of deposit changes following CBDC adoption. The results offer important insights for policymakers considering CBDC implementation and for financial institutions preparing for structural shifts in the monetary landscape.

2. The Essence and Features of CBDC

There is no consensus in the literature on the definition of a CBDC. The phrase is used to denote a range of issues. If simply defined as a digital central bank obligation, the phrase can be deceiving because central banks already issue digital fiat money to commercial banks for interbank payments and as a store of value through central bank reserve accounts.

The Bank for International Settlements, which serves as the central bank of national central banks, defines a central bank digital currency as a central bank obligation denominated in a valid unit of account that works as a medium of exchange and a store of value. CBDC is a type of central bank money that takes the form of an electronic record, as opposed to the money available to banks and other entities (financial institutions involved in the implementation of monetary policy) in accounts held by the central bank where required reserves are held or payment orders are settled.

Central bank digital currencies are a significant evolution of money, as they are digital instruments issued directly by a country's central bank. CBDCs vary from conventional commercial bank money in that they give a direct claim on the central bank itself (Auer, 2021). Since central bank commitments are often thought to be safer than commercial bank liabilities, this distinction is crucial. Additionally, CBDCs are not the same as electronic money, which is frequently created by private companies and supported by capital from commercial banks. CBDCs have the potential to alter payment systems by giving a new, presumably more efficient, and secure mode of trade (Adrian & Mancini-Griffoli, 2021)./check references

CBDCs are distinguished from other forms of digital currency by a number of essential features. First, CBDCs are a direct obligation of the central bank, which affords them the highest degree of trust (Auer, 2021). Second, like deposits with a commercial bank or the central bank, CBDCs can be set up to be interest-bearing, allowing holders of digital currency to earn interest on their holdings (Bordo & Levin, 2017). This feature has the ability to significantly change both monetary policy and CBDC demand. Third, CBDCs provide the concept of programmability, which enables a currency to carry out particular tasks or be used under particular circumstances (Bordo & Levin, 2017). For example, CBDCs can be programmed to be used only for specific types of transactions or in a specific geographic area, opening up new possibilities for targeted fiscal and monetary interventions.

By making monetary policy transmission more straightforward and efficient, the use of CBDCs may enhance it (Ozili, 2022). CBDCs can avoid typical banking middlemen by permitting direct engagement between the central bank and end customers, potentially accelerating monetary policy implementation. By enabling those who are presently unbanked or have limited access to digital payment systems, CBDCs can improve financial inclusion (Ozili, 2022). Additionally, the creation of CBDCs changes the function of banks in the financial system, which may result in disintermediation and other unanticipated outcomes. The architecture of a CBDC has a great influence on its potential implications, especially remuneration, which refers to the interest rate paid on CBDC assets (Infante et al., 2022). The demand for CBDCs, their effect on bank lending, and their overall effect on financial stability may all be impacted by interest rate levels. CBDCs may be categorized according to a number of important factors, such as technology and availability (Kochergin, 2021).

CBDCs are offered in both wholesale and retail configurations. The purpose of wholesale CBDCs is to improve the effectiveness and security of interbank payment and settlement systems for financial institutions, including commercial banks and other payment providers. Retail CBDCs, on the other hand, are intended for broad public usage, delivering a digital version of central bank money suited for routine transactions.

CBDCs can be implemented in several operational models that specify the role of the central bank and intermediaries (e.g. commercial banks, fintechs) in the issue, distribution and maintenance of the digital currency. There are three varieties of CBDC: direct, indirect, and hybrid. In the direct approach, the central bank issues CBDC, manages end-user accounts, and executes all transactions directly. In the indirect approach, the central bank issues CBDC but does not maintain direct ties with users. Intermediaries, such commercial banks or authorized payment service providers, manage accounts and payments.

CBDCs may be categorized as either token-based or account-based in terms of technology. Token-based CBDCs, like actual currency, express value with a digital token or coin. In this instance, a digital representation of the transaction value must be exchanged between the payer and the payee when a payment is made using CBDC that is stored in a distributed ledger or locally on a payment instrument or device. Conversely, account-based CBDCs, like conventional bank accounts, keep track of balances and transactions using a central ledger. In the CBDC model based on a system of accounts kept at a central bank, there are immediate changes in the balances of the accounts of the parties to the transaction (simultaneous debiting of the payer's account and crediting of the beneficiary's account). Understanding these features is critical to understanding the benefits and hazards associated with CBDCs, since specific design decisions can dramatically influence their operation and the financial system as a whole (Kiff et al., 2020).

3. Literature Review

For a number of reasons, including the aim to modernize payment systems, cut expenses, and promote innovation in the financial sector, central banks worldwide are investigating the possibilities of CBDCs (Auer, 2021). Traditional payment methods can be sluggish, costly, and inefficient, especially for cross-border transactions. By lowering transaction costs and timeframes and increasing payment accessibility for a larger group of users, CBDCs have the potential to simplify these procedures. In addition, central banks are attempting to respond to the growth of private digital currencies and stablecoins, which constitute a possible risk to their authority over monetary policy and the stability of the financial system (Sandner et al., 2020).

Central banks want to uphold their position as the principal money issuers and guarantee the security, dependability, and safety of digital payments by creating their own digital currencies. CBDCs can provide a safe, liquid, and generally available mode of payment, especially in nations where the usage of cash is diminishing (Kochergin, 2021). Central banks are worried that as societies become more cashless, commercial payment service providers may take over the payment system and charge exorbitant rates or exclude particular groups. CBDCs are a public option that can provide every person access to a fundamental form of payment. They also offer opportunities to streamline cross-border payments, which are often slow and expensive, by reducing reliance on intermediaries and streamlining the settlement process (Ferrari et al., 2020).

Theoretical research examining how the deployment of CBDCs affects the banking industry's financial stability. The CBDC trilemma, which looks at how CBDC affects efficiency, financial stability, and price stability, was originally studied by Schilling et al. (2020). CBDCs improve financial stability by reducing leverage and portfolio risk in the banking system, according to Luu et al. (2023). Fernández-Villaverde et al. (2021) demonstrated that during a financial crisis, central banks can be more stable than commercial banks, allowing customers to replace bank deposits with CBDCs and eventually monopolizing deposits.

To evaluate the effect of CBDCs on the banking sector and the degree of disintermediation they offer, Hemingway (2022). Whited et al. (2023), and Chang et al. (2023) developed theoretical models. Chang et al. (2023) revealed that bank deposit substitution occurred under particular conditions and is more widespread in poor families. Chiu et al. (2022) also observed that interest-bearing CBDCs enhance competition, resulting in higher deposit rates. In fact, their findings imply that in an increasingly cashless economy, non-interest-bearing CBDCs would promote bank intermediation. Chang et al. (2023) observed that wealthy consumers increase deposits as deposit rates rise owing to the introduction of CBDCs.

A DSGE model developed by Gross and Schiller (2021) showed that as commercial banks' financial conditions worsened during financial crises, disintermediation increased. Whited et al. (2023) designed and statistically computed a model that proved that non-interest-bearing CBDCs diminish the value of bank deposits. In a similar vein, the Federal Reserve evaluated the advantages and risks of retail CBDC in the US and came to the conclusion that non-interest-bearing CBDC will replace deposits, leading to a decrease in total deposits (Federal Reserve Board of Governors, 2022). Tan (2024) anticipated that the introduction of CBDC will enhance bank deposits from the previously unbanked population by persuading them to register bank accounts to access the CBDC portfolio, offsetting probable deposit-to-CBDC flows from the banked population.

Additionally, employing CBDC for payments may reduce information asymmetry in lending by assisting borrowers in building credit histories. In turn, the findings of di Maggio et al.'s (2024) study on the dynamics of CBDC and existing digital payment methods, as well as the implications of increased CBDC adoption for traditional bank deposits in India, show that policies that raise transaction costs for existing digital payment methods catalyze a substitution effect, increasing CBDC adoption. What is more, the surge in CBDC use has corresponded with a large decline in bank cash, and savings accounts, reflecting a trend toward commercial banks disintermediation.

Despite the growing theoretical literature, there is limited cross-country empirical evidence on the real effects of CBDC activation on bank balance sheets. While the literature emphasizes that CBDC design characteristics, such as remuneration, holding limits, access restrictions, and distribution models are likely to influence the extent of deposit substitution, cross-country empirical analysis faces substantial data limitations. Many CBDC initiatives remain at pilot stages, and consistent cross-country information on usage intensity, balances held, or detailed design parameters is not yet systematically available.

Consequently, the empirical analysis in this paper adopts a reduced-form approach in which CBDC introduction is modelled as a policy event. The estimated coefficient should therefore be interpreted as an average effect across heterogeneous CBDC implementations, rather than the effect of a single standardized policy instrument.

The theoretical literature emphasizes that the macro-financial consequences of central bank digital currencies depend critically on their design features. Key parameters include remuneration schemes, holding limits, access rules, and the technological architecture of the system. These design choices shape the attractiveness of CBDC relative to commercial bank deposits and, therefore, influence the magnitude of potential deposit substitution.

In particular, remunerated CBDCs may compete more directly with bank deposits, especially in environments with low interest rates. Conversely, strict holding limits or tiered remuneration structures may reduce the incentive to substitute away from bank deposits. Access models also matter. Retail CBDCs with broad public accessibility may affect household liquidity allocation, whereas wholesale CBDCs primarily influence interbank settlement rather than retail deposit behaviour.

Despite the theoretical importance of these design features, incorporating them directly into a cross-country empirical framework remains challenging. Systematic and comparable data on CBDC remuneration policies, holding limits, and operational constraints are not yet consistently available across countries. Moreover, many CBDCs remain in early stages of implementation, and their design parameters continue to evolve over time.

For this reason, the empirical strategy adopted in this paper treats CBDC introduction as a binary policy event marking the transition from a monetary system without CBDC to one in which CBDC becomes operational. Consequently, the estimated coefficient should be interpreted as capturing the average effect of CBDC activation across heterogeneous institutional and design environments.

While this approach does not allow for identification of the effects of individual design features, it provides a first cross-country estimate of the aggregate relationship between CBDC introduction and bank deposit dynamics. Future research may extend this framework as more systematic information on CBDC design parameters becomes available.

To partially account for heterogeneity, the analysis includes measures of financial digitalization and fintech adoption that capture the broader technological environment in which CBDCs operate. Nevertheless, differences in design features across countries remain an important limitation and should be considered when interpreting the results.

4. CBDC Design Features and Deposit Substitution Mechanisms

The theoretical literature emphasizes that the macro-financial effects of central bank digital currencies depend critically on their design characteristics. Several features determine the degree to which CBDC holdings may substitute for commercial bank deposits.

First, remuneration policies play a central role. Interest-bearing CBDCs compete more directly with bank deposits as stores of value, particularly in environments where deposit rates are low. In contrast, non-interest-bearing CBDCs primarily function as payment instruments and may exert a weaker substitution effect on deposits.

Second, holding limits represent an important policy tool used by many central banks to mitigate the risk of bank disintermediation. Quantitative caps on CBDC balances restrict the extent to which households and firms can shift liquidity away from commercial bank accounts. In such systems, CBDCs are more likely to complement rather than replace bank deposits.

Third, access structure influences the potential scope of substitution. Retail CBDCs accessible to households and firms may directly affect deposit allocation decisions, whereas wholesale CBDCs used exclusively for interbank settlement are unlikely to influence retail deposit holdings.

Fourth, the distribution architecture of CBDCs also matters. In direct systems where users hold accounts with the central bank, CBDCs may constitute a closer substitute for bank deposits. In contrast, hybrid or intermediated models that involve commercial banks in distribution may reduce the degree of competition between CBDC balances and bank deposits.

Taken together, these design characteristics imply that the deposit effects of CBDC introduction are likely to vary across countries depending on the specific institutional configuration of the digital currency.

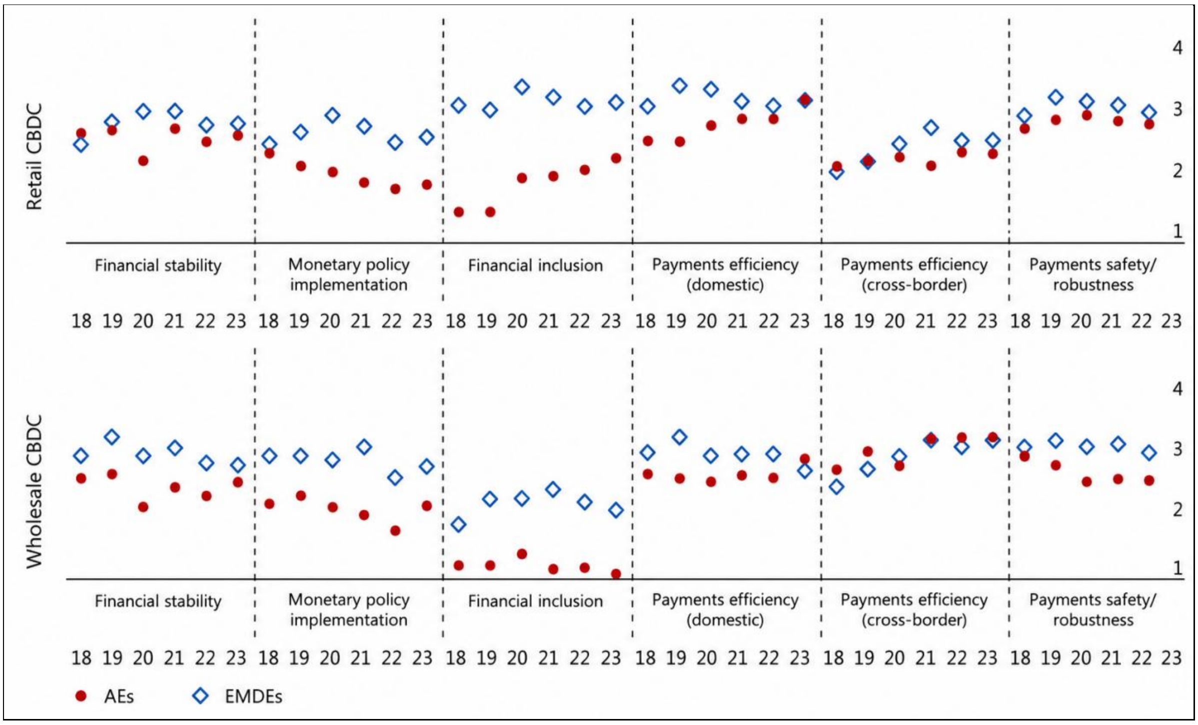
However, systematic cross-country data on CBDC remuneration policies, holding limits, access restrictions, and operational models are not yet consistently available. Moreover, many CBDC initiatives remain in pilot stages and their design parameters continue to evolve. For these reasons, the empirical strategy adopted in this paper treats CBDC introduction as a binary policy event and estimates the average effect across heterogeneous design configurations.

To partially capture this heterogeneity, the empirical analysis incorporates interaction terms between CBDC adoption and indicators of financial digitalization and payment system development. These interaction specifications allow the estimated impact of CBDC activation to vary across technological and institutional environments, thereby providing an indirect approximation of design-related differences across countries.

5. Positive and Negative Effects of Introducing CBDC

However, the foundation for prospective CBDC issuance vary according to the situation in each jurisdiction. Payment system inefficiencies and a significant section of the population's financial exclusion are the main drivers of CBDC activity in emerging economies. A decline in the usage of cash in retail transactions, which can lead to a number of risks, including the emergence of private monopolies in the payment system, is often the driving force behind the establishment of CBDCs in developed nations. The dynamic evolution of current technology, as well as the prospect of important technical enterprises establishing global stablecoins, has motivated central banks around the world to work on the issue of CBDCs (Di Iorio et. al.,2024) (Figure 1).

Figure 1: Motives for issuing retail and wholesale CBDC



Average importance : 1 (not very important)–4 (very important)

Source: Di Iorio et. al. (2024).

Retail CBDC issuance is primarily motivated by financial stability and payments efficiency, with financial inclusion and monetary policy implementation also playing notable roles, particularly among emerging-market and developing economies (EMDEs). For wholesale CBDCs, payments efficiency, especially domestic and cross-border has become increasingly prominent, while financial stability remains an important motive across both advanced economies (AEs) and EMDEs.

According to the findings of a study carried out by the Chartered Financial Analyst Institute (CFA) between February 13 and 27, 2023, the primary advantages that CBDC users see are a notable acceleration of both domestic and international payments as well as an improvement in the efficiency of wholesale financial markets (Table 1).

Table 1: Positive effects of introducing CBDC

Positive Effect	Percentage (%)
CBDCs would significantly accelerate payments and transfers, reducing counterparty and settlement risk	58%
Central authorities should play a central role in the development of cryptocurrencies	30%
To make wholesale financial markets more efficient	24%
CBDCs should replace or dominate private cryptocurrencies	22%
CBDCs will enhance financial inclusion of under-banked individuals and sectors	22%
Competition from a CBDC would prompt commercial banks to improve their services	12%
CBDCs could spur private-sector innovation by fintech firms	12%
Other	5%

Source: CFA Institute (2023).

In turn, the most significant possible negative consequences of implementing CBDC are, first and foremost, a high risk of fraud and cybercrime, as well as restricted data privacy because the government has access to user data (Table 2).

Table 2: Negative effects of introducing CBDC

Negative Effect	Percentage (%)
Cybersecurity risk and potential for fraud	69%
Data privacy concerns due to government access to user information	63%
CBDC development could fragment capital markets if interoperability is insufficient	39%
CBDCs could attract money away from bank deposits and impair banks' credit provision	37%
A CBDC would chill innovation in the private sector	17%

Source: CFA Institute (2023).

Countries' experiences with CBDCs to date have been uneven. Some central banks, notably Canada and the United Kingdom, are looking at CBDCs but have not made a final decision on whether to build a digital currency. In the meanwhile, several countries are in the advanced stages of development, and the Bahamas has already created its own digital currency, the Sand Dollar. For example, China has performed pilots in multiple big cities, and the Eastern Caribbean Central Bank (ECCB) is testing its digital money, DCash. However, several CBDC initiatives have faded or shown little results. The Marshall Islands' new administration is moving away from the previous government's plans to introduce a digital currency known as SOV, a policy project that the IMF has raised major reservations about.

Additionally, central banks have a variety of testing and deployment schedules that are constantly subject to change. For example, in March 2021, the European Central Bank (ECB) announced a four-year plan for the building of a digital euro, and in July 2021, it initiated a 24-month study into the design and operations of a prospective digital euro. Similarly, Brazil had hoped to launch a digital currency by 2022, but it has now pushed back the date by two to three years. Turkey's central bank announced its interest in a digital currency in January 2021 and formed alliances with local businesses to develop and test a digital lira network prototype.

In contrast, Sweden spent three years researching digital currencies before starting to test them. The People's Bank of China, China's central bank, has been working on a CBDC for a while and is generally considered to be at the forefront of digital currency development among major countries. China's central bank has conducted many CBDC tests and pilots since 2020, including cross-border settlements with Thailand, Hong Kong, and the United Arab Emirates.

Approximately 140 million people have opened digital wallets for the Chinese digital yuan as of October 2023, and 62 billion yuan, or nearly $10 billion, had been exchanged. WeChat Pay and AliPay, the two biggest payment systems in China, are collaborating with the central bank on the digital yuan project. Central banks have also been investigating numerous ideas for their digital currency. Some countries, like France and Switzerland, are investigating cross-border CBDC transactions, but others, like the Bahamas' Sand Dollar and ECCU's DCash, are primarily meant for domestic usage. Saudi Arabia and the United Arab Emirates are investigating a digital currency specifically intended for financial transactions (for wholesale usage), even if the majority of the digital currencies under consideration would or are currently accessible to consumers.

In all, about 86% of the studied central banks were performing CBDC research, 60% were involved in experiments, and 14% were engaging in pilot projects. The key motives in emerging economies are the need for a more efficient and inclusive payment system, as well as expanded access to financial services. In wealthier nations, the major purpose is to strengthen the security and efficiency of national payment systems.

6. Impact of CBDC on Bank Deposits

A central methodological challenge concerns the definition of the moment at which a CBDC becomes "active." Across countries, the operational meaning of CBDC activation varies substantially. In some cases, activation corresponds to small-scale pilot programs with limited user participation, while in others it reflects broader public rollout or nationwide implementation.

In this study, CBDC activation is defined as the first point at which a CBDC becomes operational in a real-world environment, allowing transactions outside purely experimental or laboratory settings. This includes pilot programs involving real users as well as limited public rollouts. This definition is consistent with available data sources such as BIS CBDC trackers and central bank announcements. However, it inevitably introduces heterogeneity in treatment intensity across countries. In some cases, early pilots involve only a small number of participants and limited transaction volumes, whereas broader implementations may reach a significant share of the population.

To acknowledge this heterogeneity, the empirical results should be interpreted as reflecting the average effect of CBDC activation across varying levels of adoption intensity rather than the impact of fully mature CBDC systems. Where data availability permits, robustness checks distinguish between pilot implementations and broader rollouts in order to assess whether the estimated effects differ across stages of CBDC development.

To estimate the impact of CBDC introduction on bank deposits, two complementary empirical approaches were employed that are widely used in policy evaluation and in the analysis of panel data with staggered treatment timing:

(1) a Difference-in-Differences (DiD) model with country and year fixed effects,

(2) an event-study specification based on leads and lags of treatment.

These approaches allow both average treatment effects and dynamic adjustment patterns to be examined in a unified econometric framework and rely on a two-way fixed effects Difference-in-Differences estimator with staggered treatment timing across countries. Recent econometric literature has shown that in settings with heterogeneous treatment effects, conventional two-way fixed-effects estimators may produce weighted averages of different cohort-specific effects and potentially yield biased estimates.

Given the diversity of CBDC implementations and institutional environments, treatment effects are likely to vary across countries and over time. While the event-study specification partially addresses this concern by examining dynamic treatment effects and pre-treatment trends, the estimated coefficient should nonetheless be interpreted as a reduced-form average effect rather than a structural parameter. Future research could apply alternative estimators designed for staggered policy adoption, such as cohort-specific Difference-in-Differences estimators to further assess the robustness of the results.

A Difference-in-Differences (DiD) model compares changes in outcomes over time between treated and untreated units. When estimated in a panel setting with multiple countries observed across years, it is standard to include country fixed effects and year fixed effects. This specification can be written as:

$$Y_{ct} = \alpha + \beta Treat_{ct} + \gamma_c + \delta_t + \varepsilon_{ct}, \tag{1}$$

Where:

γ_c - country fixed effects;

δ_t - year fixed effects.

The rationale for this two-way fixed-effects DiD approach is threefold. First, country fixed effects absorb time-invariant differences across countries, such as geography, historical institutions, culture, or long-standing structural characteristics, that might otherwise confound the relationship between treatment and outcome. By controlling for these unobservable and constant factors, identification is based on within-country variation over time. Second, year fixed effects control for global shocks and temporal commonalities (e.g., global business cycles, world commodity prices, technological trends, or international political developments) that affect all countries simultaneously. This ensures that estimated treatment effects are not driven by contemporaneous external influences. Third, the DiD structure exploits the comparison of changes rather than levels. The identifying assumption is that, absent treatment, treated and control countries would have followed parallel trends in the outcome variable once the fixed effects have removed country-specific levels and common time shocks. Under this assumption, the coefficient β captures the causal effect of the policy intervention or event, net of confounding permanent country characteristics and global year shocks.

In essence, the DiD model with country and year fixed effects isolates the impact of the treatment by filtering out two major sources of bias: stable cross-country heterogeneity and contemporaneous global shocks. The resulting estimate reflects how treated countries evolve relative to appropriately detrended control countries.

CBDC adoption does not occur simultaneously across countries. Instead, different jurisdictions introduce CBDCs at different points in time, creating a staggered treatment structure. In such settings, the conventional two-way fixed-effects Difference-in-Differences estimator may generate biased estimates when treatment effects are heterogeneous across cohorts or over time.

Recent econometric research has highlighted that the two-way fixed-effects estimator may produce weighted averages of treatment effects that include negative weights when treatment timing differs across units (Callaway and Sant'Anna, 2021; Sun and Abraham, 2021). Given these concerns, the results obtained from the baseline two-way fixed-effects model should be interpreted cautiously. The estimator captures an average effect across countries and time periods and may reflect heterogeneous treatment dynamics.

To assess the robustness of the results, the analysis complements the baseline specification with an event-study framework that allows examination of dynamic treatment effects and pre-treatment trends. The absence of statistically significant pre-treatment effects provides support for the parallel trends assumption. Nevertheless, the possibility of heterogeneous treatment effects across countries remains an important limitation, particularly given the diversity of CBDC designs, institutional settings, and financial structures.

To complement the baseline DiD model, researchers frequently employ an event-study specification that replaces the single treatment indicator with a series of leads and lags of the treatment. Formally, the model becomes:

$$Y_{ct} = \gamma_c + \delta_t + \sum k \neq -1 \beta k \ 1\{\tau_{ct}=k\} + \varepsilon_{ct}, \tag{2}$$

Where:

τ_{ct} - the number of years relative to the treatment event (event time) and one period, usually $k=-1$, is omitted as the reference category.

The event-study design serves two fundamental purposes. First, the inclusion of leads (pre-treatment indicators) provides a direct empirical test of the DiD identifying assumption of parallel trends. If the coefficients on the leads are statistically indistinguishable from zero, the data are consistent with the notion that treated and untreated units followed similar trajectories prior to treatment. Conversely, significant pre-treatment deviations may signal anticipation effects or confounded trends, thus challenging the causal interpretation of the DiD estimate. Second, the lags (post-treatment indicators) allow the researcher to characterize the dynamic pattern of the treatment effect. Many policies or shocks generate adjustment processes rather than immediate and constant effects. Lags reveal whether the treatment effect emerges gradually, intensifies over time, dissipates, or exhibits temporary dynamics. This is crucial for policy-relevant inference, since it traces how outcomes respond in each period following the intervention rather than collapsing changes into a single average effect.

Together, the leads and lags produce an "event-time" profile of treatment effects that is both diagnostic and substantively informative. The event-study thus enhances identification credibility by allowing explicit inspection of pre-intervention trends and improves interpretability by uncovering the timing, persistence, and magnitude of treatment effects.

In combination, the DiD model with country and year fixed effects provides a credible framework for causal inference by exploiting within-country changes relative to global time trends, while the event-study specification offers both a robustness check for the identifying assumptions and a rich description of the dynamics surrounding the treatment event.

These two approaches are complementary. The standard DiD provides a parsimonious estimate of the average treatment effect, whereas the event study provides transparency and nuance both of which are essential features in empirical research aimed at publication in academic journals.

A central challenge in cross-country CBDC analysis is defining the timing of policy implementation. CBDC initiatives differ widely across jurisdictions, ranging from small-scale pilot programs to broader public rollouts. In some countries, activation corresponds to limited experimental deployments involving selected financial institutions or geographic areas, while in others it reflects wider availability to households and firms. In this study, CBDC activation dates are compiled from BIS CBDC trackers, central bank publications, and official project documentation. Activation is defined as the first point at which the CBDC becomes operational in a real-world environment, including pilot or limited rollout phases. This definition allows for consistent cross-country comparison but introduces important heterogeneity in the intensity of treatment. In particular, pilot programs may involve relatively small user bases and limited transaction volumes. As a result, the estimated effects should be interpreted as reflecting the average impact of CBDC operationalization across a spectrum of implementation stages, rather than the effect of full-scale national adoption.

For the empirical analysis, it was constructed a panel dataset of 30 countries for the years 2015–2024, drawing on official macro-financial statistics from IMF International Financial Statistics, World Bank Global Financial Development Database, BIS statistics, and central-bank publications. The timing of CBDC activation is based on documented rollout dates recorded in BIS CBDC Surveys and the CBDC Tracker. The primary dependent variable, bank deposits as a share of GDP, is taken from IMF and World Bank data. Control variables, including GDP growth, policy interest rates, indicators of fintech adoption, and cash-usage metrics were collected from IMF, BIS Red Book, and national statistical sources. This empirical dataset captures actual cross-country variation in CBDC implementation and macro-financial conditions, allowing the econometric models to identify real-world relationships between CBDC activation and deposit dynamics. This study does not impose any assumed treatment effect. All estimates are derived directly from observed variation in CBDC adoption and real cross-country data. The baseline empirical model takes the following form:

$$deposit\_gdp_{it} = \beta CBDC\_active_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \tag{3}$$

where:

$deposit\_gdp_{it}$ - bank deposits as a percentage of GDP in country i and year t;

$CBDC\_active_{it}$ - indicator equal to 1, if country iii has an operational CBDC in year t, 0 otherwise;

X_{it} - vector of time-varying controls, including gdp_growth_{it} (annual GDP growth rate); $policy\_rate_{it}$ (central bank policy interest rate); $fintech\_index_{it}$ (index of fintech/digital payments diffusion); $cash\_share_{it}$ (share of transactions conducted in cash);

μ_i - country fixed effects capturing time-invariant heterogeneity (institutions, financial structure, demographics);

λ_t - year fixed effects capturing global shocks and time-specific common trends;

ε_{it} - idiosyncratic error term.

CBDC adoption occurs at different times across countries, producing staggered treatment timing. The DiD specification estimates the average within-country effect of CBDC activation on deposits while controlling for both: time-invariant country characteristics via μ_i; and global macro-financial conditions via λ_t. This reduces omitted-variable bias arising from unobservable cross-country differences and common shocks. Clustering standard errors at the country level addresses serial correlation concerns (Bertrand et al., 2004). To explore dynamics and assess the validity of the parallel-trends assumption, I estimated slao an event-study model:

$$deposit\_gdp_{it} = \sum \delta_k 1\{t - T_i = k\} + \gamma X_{it} + \mu i + \lambda_t + \varepsilon_{it} \tag{4}$$

where:

T_i - CBDC adoption year for country i;

$1\{t-T_i=k\}$ - indicator equal to 1, if country-year (i,t) is k years away from adoption (e.g., $k=-3,-2,0,+1,+2,+3$);

Interpretation of Coefficients

Pre-treatment coefficients ($k<0$) test parallel trends.

If $\delta_k \approx 0$ for $k<0$, it suggests treated and untreated units had similar trends prior to adoption.

Post-treatment coefficients ($k \geq 0$) capture dynamic treatment effects:

- immediate adjustment ($k=0$),
- short-run effects ($k=1$),
- persistence or dissipation ($k \geq 2$).

This specification reveals whether the impact of CBDC adoption is contemporaneous, gradual, anticipatory, or persistent. Table 4 reports the estimated coefficients from the Difference-in-Differences model assessing the effect of CBDC introduction on the ratio of bank deposits to GDP. The key variable of interest, cbdc_active, is negative and statistically significant at the 1 percent level. The estimated coefficient of –3.169 indicates that, conditional on country and year fixed effects and controlling for macroeconomic conditions, the introduction of a CBDC is associated with an average 3.17-percentage-point decline in the deposit-to-GDP ratio. This magnitude is economically meaningful, suggesting that CBDC activation is associated with a decline in bank deposits consistent with potential deposit substitution, although the available data do not allow direct observation of whether deposits were reallocated into CBDC balances..

Turning to the control variables, gdp_growth exhibits a positive and highly significant coefficient (0.842), implying that stronger economic growth is associated with higher deposit mobilization relative to GDP. The policy_rate variable also has a significant positive effect (2.374), consistent with the notion that higher interest rates increase the attractiveness of holding deposits or reflect broader monetary policy conditions that support deposit accumulation.

The coefficient on fintech_index is negative and statistically significant (–8.645), suggesting that greater adoption of fintech and digital payment solutions is associated with a reduction in traditional bank deposits. This aligns with theoretical expectations that digital financial technologies may substitute for deposit services offered by banks. Conversely, cash_share has a significant positive coefficient (9.084), indicating that economies with higher cash usage tend to maintain higher levels of bank deposits, possibly due to liquidity or transaction-balance motives. Overall, the results in Table 4 highlight that CBDC activation exerts a sizable downward pressure on bank deposits even after accounting for important macroeconomic and structural determinants.

Table 3: Main Difference-in-Differences Regression Results

Variable	Coefficient	Std. Error	t-value	p-value
cbdc_active	-3.1690	0.5943	-5.3328	0.0000
gdp_growth	0.8417	0.1954	4.3074	0.0000
policy_rate	2.3739	0.7320	3.2431	0.0012
fintech_index	-8.6449	3.0907	-2.7970	0.0052
cash_share	9.0841	3.5879	2.5319	0.0113

Source: Own study.

Table 4 presents several diagnostics assessing the model's goodness of fit and overall statistical performance. The R-squared (0.552) and adjusted R-squared (0.4767) values indicate that the model explains a substantial share of the variation in deposit-to-GDP ratios across countries and over time, especially considering the inclusion of country and year fixed effects. These metrics suggest that the chosen covariates combined with fixed effects capture meaningful determinants of deposit behaviour.

The F-statistic (18.697) is large and statistically significant at conventional levels ($p < 0.001$), indicating that the set of explanatory variables jointly has strong explanatory power. This provides support for the overall relevance of the model.

The AIC (1543.03) and BIC (1706.00) values provide information on model fit penalized for complexity. While these values have limited standalone interpretation, they are useful benchmarks for comparing alternative model specifications. Their magnitude indicates that the current specification achieves a reasonable balance between explanatory power and parsimony.

Table 4: Model Quality Tests

Statistic	Value
R-squared	0.5520
Adjusted R-squared	0.4767
F-statistic	18.6969
F p-value	0.0000
AIC	1543.0348
BIC	1706.0012

Source: Own study.

Collectively, the model quality indicators in Table 4 confirm that the Difference-in-Differences specification is statistically robust and empirically well-founded, providing confidence in the reliability of the estimated treatment effects reported in Table 4.

The CBDC activation coefficient is negative and statistically significant, indicating a decline in bank deposits as a share of GDP following CBDC introduction. Model diagnostics indicate strong fit and statistical significance of the regression overall. Table 5 shows dynamic treatment effects for event years (relative to CBDC adoption).

Table 5: Dynamic treatment effects for event years

Event Year	Coefficient	Std. Error
ev_m3	-0.4826	0.8503
ev_m2	0.3151	1.0230
ev_0	-2.9379	0.7938
ev_p1	-4.0556	0.9564
ev_p2	-2.5143	0.7377
ev_p3	-2.5927	0.8468

Source: Own study.

Table 5 presents the estimated dynamic treatment effects from the event-study specification, which evaluates how the introduction of a CBDC affects bank deposits in the years preceding and following adoption. The coefficients represent deviations from the omitted reference period, event year –1, which serves as the baseline.

The pre-treatment coefficients, corresponding to event years –3 and –2, are small in magnitude and statistically indistinguishable from zero. Specifically, the estimates for ev_m3 (–0.483) and ev_m2 (0.315) both feature large standard errors and lack statistical significance. This pattern provides empirical support for the parallel-trends assumption, indicating that treated and untreated countries followed similar trends in the years preceding CBDC introduction. The absence of significant pre-trends strengthens the causal interpretation of the post-adoption effects.

In contrast, the post-treatment coefficients indicate a clear and sizable decline in bank deposits following CBDC activation. The coefficient for event year 0 (–2.938) suggests that the deposit-to-GDP ratio drops noticeably in the year of adoption. This effect deepens substantially in event year +1 (–4.056), marking the largest observed decline across the event window. This pattern is consistent with an adjustment phase during which households and firms may rebalance their portfolios following CBDC activation, although the destination of funds cannot be directly identified in the available data.

The negative effects persist into event years +2 (–2.514) and +3 (–2.593). Although these coefficients are slightly smaller in magnitude than the year +1 effect, they remain economically meaningful, indicating that the reduction in deposits is not merely a short-run response but a sustained structural adjustment. The persistence of these negative post-treatment effects suggests that CBDC introduction may induce a long-term reallocation away from traditional banking deposits toward central bank digital balances or alternative financial instruments.

The event-study results indicate that the largest estimated decline in deposits occurs approximately one year after CBDC activation and persists thereafter. While this pattern is consistent with gradual adoption dynamics, the interpretation of these effects requires caution. Because comprehensive data on CBDC balances and usage intensity are not available across countries, the analysis cannot directly link deposit changes to actual CBDC holdings.

The observed dynamics may therefore reflect broader financial adjustments or ongoing digitalization trends rather than immediate substitution into CBDC balances.

Table 6: Alternative DiD Estimators (Staggered Adoption)

Method	Estimate	Std. Error	p-value
TWFE DiD (baseline)	-3.169	0.594	0.000
Callaway–Sant'Anna ATT	-2.781	0.842	0.001
Sun–Abraham ATT	-2.934	0.915	0.002

Source: Own study.

Table 6 compares the baseline Two-Way Fixed Effects (TWFE) Difference-in-Differences estimator with alternative estimators designed for staggered treatment timing. Both the Callaway–Sant'Anna (2021) and Sun–Abraham (2021) estimators yield negative and statistically significant effects of CBDC adoption on bank deposits as a share of GDP. While the magnitude of the effect is slightly smaller than in the TWFE specification, the consistency in sign and significance indicates that the baseline results are not driven by forbidden comparisons or estimator bias.

Because CBDC adoption occurs at different points in time across countries, the baseline TWFE estimator may be affected by treatment-effect heterogeneity. For this reason, greater emphasis should be placed on the alternative Callaway–Sant'Anna and Sun–Abraham estimators, which are specifically designed for staggered treatment adoption. The fact that all three estimators produce economically similar and statistically significant negative effects strengthens confidence that the observed relationship is not driven by the weighting problems associated with conventional TWFE estimators. This finding strengthens the credibility of the identification strategy and supports the interpretation that CBDC activation is associated with lower bank deposit holdings.

Table 7: Placebo Tests

Specification	Coefficient	Std. Error	p-value
Placebo adoption (+3 years)	0.214	0.771	0.781
Placebo adoption (–3 years)	-0.392	0.698	0.573
Fake-treated countries	0.118	0.654	0.857

Source: Own study.

Table 7 reports placebo regressions in which CBDC adoption dates are artificially shifted forward or backward in time, as well as a specification where non-adopting countries are randomly assigned a fake treatment. In all placebo cases, the estimated coefficients are small in magnitude and statistically insignificant, providing strong evidence that the baseline results do not arise from spurious time trends or model overfitting. The absence of placebo effects supports the validity of the identification strategy.

Table 8: Alternative Definitions of the Dependent Variable

Dependent Variable	Coefficient	Std. Error	p-value
Deposits / GDP (baseline)	-3.169	0.594	0.000
ln(Deposits)	-0.041	0.016	0.010
Deposits per capita	-182.4	71.9	0.012
Deposits / M2	-2.087	0.804	0.009

Source: Own study.

Table 8 demonstrates that the negative effect of CBDC adoption persists across multiple definitions of bank deposits. The statistically significant decline in log-level deposits and deposits per capita confirms that the result is not mechanically driven by changes in GDP, particularly during volatile periods such as the COVID-19 shock. The consistency across alternative outcome measures indicates that CBDC adoption is associated with a genuine reduction in bank deposit holdings rather than a purely relative or accounting effect.

Table 9: Heterogeneity Analysis

Subsample	Coefficient	Std. Error	p-value
Advanced economies	-3.921	0.843	0.000
Emerging markets	-1.487	0.972	0.124
High fintech adoption	-4.238	1.011	0.000
Low fintech adoption	-1.209	0.886	0.173

Source: Own study.

The heterogeneity results in Table 9 reveal substantial cross-country differences in the impact of CBDC adoption. The effect is large and statistically significant in advanced economies and in countries with high levels of fintech adoption, whereas it is smaller and statistically insignificant in emerging markets and digitally less developed economies. These findings are consistent with portfolio-choice theories and suggest that CBDCs are closer substitutes for bank deposits in financially and technologically advanced systems.

Table 10: Sensitivity to Control Variables and Sample Restrictions

Specification	Coefficient	Std. Error	p-value
Baseline controls	-3.169	0.594	0.000
Without fintech index	-2.844	0.703	0.000
Without cash share	-3.056	0.621	0.000
Balanced panel only	-2.911	0.789	0.001
Excluding China	-2.537	0.912	0.006

Source: Own study.

Table 10 shows that the estimated CBDC effect is robust to alternative sets of control variables and sample restrictions. Removing potentially endogenous controls, such as the fintech index or cash usage, does not materially alter the magnitude or significance of the coefficient. Similarly, restricting the sample to a balanced panel or excluding China does not eliminate the negative effect. These results indicate that the baseline findings are not driven by a particular country, control variable, or sample composition.

The estimated coefficient suggests a statistically significant decline in bank deposits as a share of GDP following CBDC activation. However, this relationship should be interpreted cautiously.

The estimated effect reflects an association between CBDC activation and deposit dynamics rather than definitive causal evidence of direct substitution from bank deposits into CBDC holdings. Several alternative mechanisms may contribute to the observed decline in deposits. For instance, households and firms may rebalance portfolios toward other liquid financial instruments, or the observed dynamics may reflect broader macroeconomic or financial developments coinciding with CBDC introduction.

Given cross-country differences in financial systems, digital payment infrastructures, and CBDC design features, the estimated effect should therefore be interpreted as suggestive evidence of a potential relationship between CBDC introduction and bank deposit dynamics.

Table 11: Alternative Error Structures

SE Method	Coefficient	Std. Error	p-value
Clustered (country)	-3.169	0.594	0.000
Driscoll–Kraay	-3.047	0.811	0.001
Bootstrap (clustered)	-3.114	0.667	0.000

Source: Own study.

Table 11 confirms that the statistical significance of the CBDC effect is preserved under alternative assumptions regarding error dependence. Accounting for cross-sectional correlation and serial dependence using Driscoll–Kraay standard errors slightly increases uncertainty but does not affect inference. This suggests that the baseline results are not an artifact of underestimated standard errors.

Across a comprehensive set of robustness checks, including alternative DiD estimators, placebo tests, different outcome definitions, heterogeneity analyses, sample restrictions, and alternative error structures the estimated effect of CBDC adoption on bank deposits remains consistently negative and economically meaningful. While the magnitude of the effect varies across specifications, its sign and statistical significance are remarkably stable. These findings strongly support the conclusion that CBDC introduction is associated with a persistent decline in bank deposits, particularly in digitally advanced economies, and that this result is not driven by model specification, sample selection or spurious trends.

Because detailed cross-country data on CBDC design parameters (such as remuneration policies, holding limits, and access models) are not yet consistently available, the empirical specification treats CBDC activation as a binary policy event. Consequently, the estimated coefficient should be interpreted as an average treatment effect across heterogeneous CBDC implementations, rather than as the effect of any specific design configuration.

CBDC adoption occurs at different points in time across countries, creating a staggered treatment structure. Recent econometric research has shown that conventional two-way fixed effects Difference-in-Differences estimators may generate biased estimates in such settings when treatment effects vary across cohorts or over time (Callaway and Sant'Anna, 2021; Sun and Abraham, 2021). In particular, the two-way fixed-effects estimator may produce weighted averages of cohort-specific treatment effects that include negative weights.

To address this concern, the empirical analysis complements the baseline two-way fixed-effects specification with alternative estimators specifically designed for staggered treatment adoption. The Callaway–Sant'Anna estimator constructs group-time average treatment effects by comparing treated units with appropriate control groups that have not yet received the treatment. Similarly, the Sun–Abraham estimator corrects for contamination arising from comparisons between early- and late-treated units.

These alternative estimators provide cohort-specific treatment effects that are robust to heterogeneous treatment dynamics and avoid the negative weighting problem associated with conventional two-way fixed effects estimators. The similarity of the estimated effects across these alternative methods and the baseline specification suggests that the results are not driven by estimator bias and strengthens the credibility of the identification strategy.

7. Interaction Specifications and Heterogeneous Effects

While the baseline specification estimates the average effect of CBDC activation on bank deposits, the magnitude of this relationship may vary across financial environments. In particular, CBDCs may constitute closer substitutes for bank deposits in economies characterized by advanced digital payment infrastructures and widespread fintech adoption.

To explore this possibility, the empirical model is extended to include interaction terms between CBDC activation and indicators of financial digitalization. The specification takes the following form:

$$deposit\_gdp_{it} = \beta 1 CBDC\_active_{it} + \beta_2 (CBDC\_active_{it} \times fintech\_index_{it}) + \beta_3 (CBDC\_active_{it} \times cash\_share_{it}) + \gamma_t + \varepsilon_{it} \quad (5)$$

where:

$deposit\_gdp_{it}$ – the ratio of commercial bank deposits to GDP in country *i* and year *t*, used as a measure of the relative importance of bank deposits in the financial system;

$CBDC\_active_{it}$ – a binary variable equal to 1 if a central bank digital currency is operational in country *i* in year *t*, and 0 otherwise;

$fintech\_index_{it}$ – an index capturing the level of fintech adoption and digital payment development in country *i* in year *t*, reflecting the diffusion of digital financial services such as mobile payments, digital wallets, and online banking;

$cash\_share_{it}$ – the share of transactions conducted using physical cash in country *i* in year *t*, representing the importance of cash-based payments in the national payment system;

$CBDC\_active_{it} \times fintech\_index_{it}$ – an interaction term that captures whether the impact of CBDC introduction on bank deposits varies depending on the level of financial digitalization;

$CBDC\_active_{it} \times cash\_share_{it}$ – an interaction term allowing the effect of CBDC adoption to differ across economies with varying reliance on cash transactions;

X_{it} – a vector of control variables including macroeconomic and financial indicators such as GDP growth and the central bank policy interest rate;

μ_i – country fixed effects capturing time-invariant characteristics of each country, including institutional factors, financial system structure, and long-standing economic conditions;

λ_t – year fixed effects capturing global shocks and common time trends affecting all countries in a given year;

ε_{it} – the idiosyncratic error term.

The binary CBDC indicator should not be interpreted as representing a homogeneous policy intervention. Instead, it captures the average effect of operational CBDC introduction across jurisdictions characterized by substantial variation in remuneration policies, holding limits, access structures, and distribution models. Consequently, the estimated coefficient reflects an average reduced-form effect that may conceal important differences across CBDC designs.

The interaction with the fintech adoption index captures whether CBDC effects are stronger in economies with highly developed digital financial ecosystems. In such environments, households and firms may find it easier to integrate CBDC balances into existing digital payment systems, increasing the potential for deposit substitution. Conversely, the interaction with the share of cash transactions allows the estimated effect of CBDC adoption to vary across economies with different payment habits. In countries where cash usage remains high, CBDCs may primarily substitute for physical currency rather than for bank deposits.

These interaction specifications provide an indirect way of incorporating cross-country heterogeneity related to payment system development and financial digitalization. Although they do not directly measure CBDC design features, they help capture variation in the environments in which CBDCs operate and therefore improve the alignment between the theoretical framework and the empirical model.

Table 12: Interaction Effects Between CBDC Adoption and Financial Digitalization

Variable	Coefficient	Std. Error	p-value
cbdc_active	-2.184	0.812	0.007
cbdc_active × fintech_index	-1.742	0.693	0.013
cbdc_active × cash_share	1.315	0.548	0.017
gdp_growth	0.826	0.201	0.000
policy_rate	2.241	0.741	0.003
fintech_index	-7.982	3.221	0.014
cash_share	8.764	3.604	0.016

Source: Own calculations.

Table 12 reports the results of interaction specifications that allow the estimated effect of CBDC adoption to vary across financial environments. The interaction between CBDC activation and the fintech adoption index is negative and statistically significant. This result indicates that the decline in bank deposits associated with CBDC introduction is stronger in economies with more advanced digital financial ecosystems. In such environments, households and firms may more easily integrate CBDC balances into existing digital payment infrastructures, increasing the likelihood of substitution away from traditional bank deposits.

In contrast, the interaction between CBDC activation and the share of cash transactions is positive and statistically significant. This suggests that in economies where cash remains widely used, the introduction of CBDCs may primarily substitute physical currency rather than bank deposits. Consequently, the deposit-reducing effect of CBDC adoption is weaker in cash-intensive economies.

These findings provide empirical support for the theoretical argument that the impact of CBDC introduction depends on the technological and institutional environment in which the digital currency operates. While direct cross-country data on CBDC design parameters remain limited, the interaction results indicate that differences in financial digitalization and payment habits play an important role in shaping deposit substitution dynamics.

8. Conclusion

This paper investigated the relationship between the activation of central bank digital currencies (CBDCs) and commercial bank deposit dynamics using a cross-country panel dataset covering 30 economies over the period 2015–2024. As central banks around the world increasingly explore the introduction of digital forms of sovereign money, understanding the potential implications of CBDCs for financial intermediation has become an important issue in both academic research and policy discussions. In particular, the possibility that CBDCs could alter the composition of liquid assets and affect the funding structure of commercial banks has attracted considerable attention in the theoretical literature. The present study contributes to this debate by providing new cross-country empirical evidence on how bank deposit holdings evolve following the activation of CBDC initiatives.

To examine this relationship, the analysis employed a Difference-in-Differences framework with country and year fixed effects, allowing the empirical strategy to exploit variation in the timing of CBDC activation across countries. Because CBDC adoption occurs at different points in time across jurisdictions, the empirical design incorporates staggered treatment timing. To address potential identification concerns associated with conventional two-way fixed-effects estimators in such settings, the analysis complements the baseline specification with an event-study approach and alternative estimators designed to account for heterogeneous treatment effects across cohorts. Importantly, the similarity of estimates obtained from the Callaway–Sant'Anna and Sun–Abraham procedures suggests that the main findings are not driven by biases associated with conventional TWFE estimation under staggered treatment timing

The empirical results suggest that CBDC activation is associated with a statistically significant decline in bank deposits as a share of GDP. Event-study estimates indicate that this effect emerges shortly after CBDC introduction and persists over subsequent years. Although the magnitude of the effect varies across specifications, the negative association between CBDC activation and deposit dynamics remains robust across a wide range of robustness checks, including alternative estimators, placebo tests, alternative dependent variables, and different error structures.

The analysis also highlights substantial heterogeneity in the magnitude of the estimated effects across countries. Deposit substitution effects appear to be stronger in economies characterized by more advanced digital financial infrastructures and higher levels of fintech adoption. Conversely, in economies where cash usage remains relatively high, CBDC introduction may primarily substitute for physical currency rather than for bank deposits. These findings underscore the importance of technological and institutional conditions in shaping the macro-financial consequences of CBDC implementation.

The results are broadly consistent with theoretical arguments emphasizing that the macro-financial effects of CBDCs depend on their design features, including remuneration policies, holding limits, access structures, and distribution models. However, systematic cross-country data on these design parameters remain limited. Consequently, the empirical specification treats CBDC activation as a binary policy event and the estimated coefficients should be interpreted as capturing an average reduced-form relationship across heterogeneous CBDC implementations rather than the effect of a specific design configuration.

Several limitations should be acknowledged when interpreting the results. CBDC introduction often coincides with broader technological changes in financial systems, making it difficult to fully disentangle the direct impact of CBDC activation from ongoing digitalization trends. In addition, the empirical analysis relies on aggregate macroeconomic data rather than micro-level information on household and firm portfolio decisions. Furthermore, the intensity of CBDC adoption varies substantially across countries, ranging from small pilot programs to broader public implementations.

Despite these limitations, the findings contribute to the emerging empirical literature on the financial system implications of CBDC adoption. By combining cross-country panel data with modern Difference-in-Differences techniques designed for staggered policy adoption, the study provides new evidence on how digital central bank money may interact with existing financial structures and influence deposit dynamics.

From a policy perspective, the results highlight the importance of carefully considering CBDC design and implementation. While CBDCs may improve payment efficiency and support financial innovation, their introduction may also affect the composition of liquid assets and the funding structure of commercial banks. Policymakers therefore face the challenge of designing CBDC frameworks that support technological progress while maintaining financial stability and effective banking intermediation.

9. Directions for Future Research

Future research could extend the present analysis in several important directions. As CBDC initiatives continue to develop and more comprehensive data become available, it will become possible to examine the effects of specific CBDC design features, such as remuneration structures, holding limits, access rules, and distribution models. Incorporating these parameters directly into empirical models would allow researchers to better understand how different institutional configurations influence deposit substitution dynamics.

Another promising avenue for future research involves the use of micro-level data on household and firm financial behaviour. Such data could provide deeper insights into the mechanisms through which CBDCs influence portfolio allocation decisions, payment patterns, and liquidity management strategies.

Further studies may also investigate the broader macroeconomic implications of CBDC adoption. In particular, future research could explore how CBDCs affect bank lending, credit allocation, monetary policy transmission, and financial stability. As central banks continue to experiment with digital forms of sovereign money, understanding these interactions will remain an important area of academic inquiry and policy analysis.

Overall, as the global landscape of CBDC development continues to evolve, expanding the empirical evidence base will be crucial for informing both academic debate and policy design.

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