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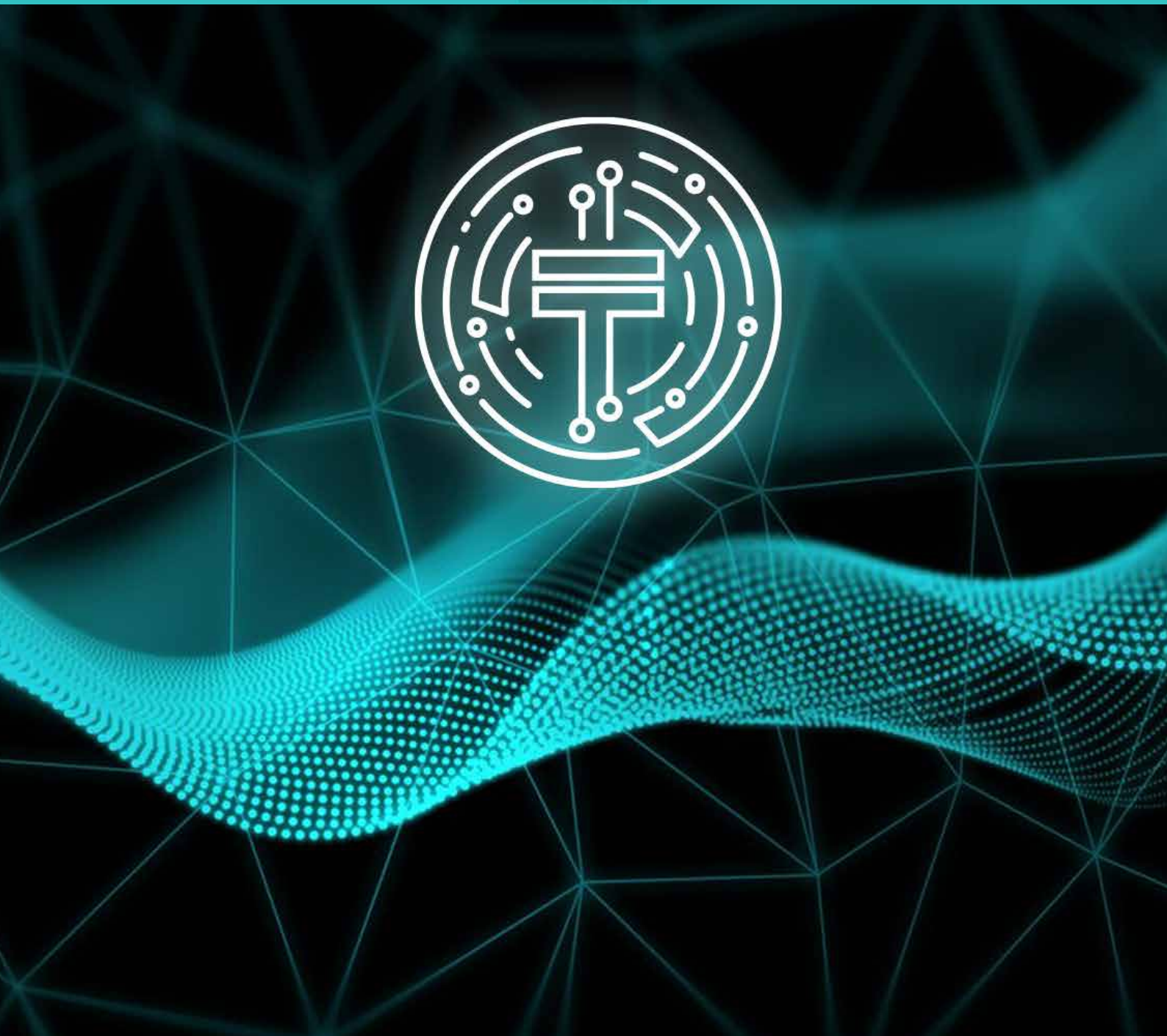
Central Bank Digital Currency (CBDC):

From Global Challenges to Implementation in Kazakhstan



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1 Summary

Interest in central bank digital currencies (CBDCs) has grown rapidly in recent years, however, the pace of their implementation varies significantly across countries.

During pilot projects, regulators face technological, institutional, and behavioral barriers. These difficulties do not call into question the very idea of a CBDC, but they highlight the need for an in-depth analysis of the factors influencing the success of implementation.

This study identifies the key challenges countries face in implementing CBDCs and explores potential solutions based on international experience. The report outlines five major barriers identified through pilot and research initiatives:

- low awareness among consumers and businesses
- high investment burden on the banking sector
- uncertainty regarding benefits for banks
- technological and infrastructure constraints
- competition from traditional payment methods

Each of these challenges is examined through the lens of practical case studies — from China and India to countries in the Middle East, Europe, and the Caribbean. The analysis demonstrates that successful CBDC implementation requires not only technological readiness but also the development of a robust ecosystem of interaction among governments, businesses, and citizens.

Particular attention is given to the experience of Kazakhstan, where the Digital Tenge project has become part of a broader strategy to strengthen the country's financial sovereignty and technological independence. The report demonstrates that Kazakhstan has adapted international approaches to its domestic economic context, leveraging programmability use cases to enhance transparency in public spending, automate tax calculations, and foster the development of an innovative financial infrastructure.

Despite systemic challenges, international experience confirms that, with a well-designed architecture, a phased implementation approach, and effective coordination between the regulator, financial institutions, and businesses, the barriers to CBDC adoption can be successfully overcome.

This study is the result of a joint effort between the National Payment Corporation of the National Bank of the Republic of Kazakhstan (hereinafter referred to as the NPC NBK) and Axellect, acting as the technology partner for the Digital Tenge project

2 Introduction

Over the past decade, central bank digital currencies have evolved from a research concept into one of the key trends in the global financial system. More than 100 countries, accounting for over 98% of global GDP, are conducting research and launching pilots of their own CBDC projects.

Global experience shows that while countries' motivations for introducing national digital currencies vary, they share common objectives — strengthening financial sovereignty, combating the shadow economy, improving the efficiency of public spending, and fostering innovation in payment infrastructure.

Beyond macroeconomic objectives, the introduction of CBDCs also creates new opportunities for participants in the financial system. For individuals, this includes enhanced protection of funds and a state guarantee of their safety, even in the event of a bank default. For merchants, it offers reduced payment processing costs, as well as increased transparency and security of transactions.

China and the Bahamas have been pioneers in developing traditional retail CBDCs: the e-CNY and the Sand Dollar have demonstrated that CBDCs can operate at scale in mass circulation, enabling high-volume retail transactions. In Europe and Canada, central banks are exploring the potential of digital currencies as a monetary policy tool, while India and Brazil are considering CBDCs as a means to expand financial inclusion and reduce transaction costs.

For Kazakhstan, the digital tenge represents a logical step in the evolution of the national payment ecosystem. Its implementation builds on an already established payment infrastructure and a rapidly growing fintech sector. Kazakhstan has adopted a two-tier model, in which the National Bank of the Republic of Kazakhstan (NBRK) is responsible for issuance and control of the national digital currency, while commercial banks and fintech companies provide end users with access to services. This approach combines innovation with stability, reduces the burden on market participants, and supports the development of competition.

The digital tenge is considered not only as a tool for modernizing the payment system, but also as a strategic component of a sovereign digital economy. Its application unlocks new opportunities for automating transactions, ensuring targeted use of public funds, and reducing the shadow economy. Kazakhstan's experience demonstrates that CBDC implementation can serve as a catalyst for a profound transformation of the financial sector, where technology becomes the foundation of trust and transparency.

3 Drivers and strategic objectives of CBDC implementation

The approach of central banks to digital currencies has evolved significantly in recent years. The initial phase of enthusiasm and high expectations has given way to a more mature and pragmatic understanding of the role of CBDC within the financial system.

As a result, regulators have shifted their focus toward identifying and developing practical use cases that can deliver the greatest economic impact. This process is driven not only by technological considerations, but also by a broad set of macroeconomic, social, and regulatory factors that are common across countries with varying levels of economic development.

Reduction of the shadow economy

CBDCs enhance transaction transparency, reduce the volume of illicit financial flows, and improve the effectiveness of anti-money laundering and counter-terrorist financing (AML/CFT) mechanisms. The marking of CBDCs simplifies tax compliance monitoring and increases collection in the government budget.

Anti-corruption efforts

CBDCs enable regulators to monitor the movement of public funds in real time and ensure targeted use of budget resources. A national digital currency creates conditions for transparent distribution of subsidies, grants, and social payments, minimizing the risk of inappropriate spending.

Diversification of payment rails

Unlike traditional payment systems, CBDCs offer advanced functionality, including programmable payments, integration with smart contracts, automatic settlements, and targeted use of funds.

Strengthening economic and technological sovereignty

In the context of dependence on foreign payment systems, central banks seek to reduce external risks and strengthen the role of the national currency.

Macroeconomic regulation

Direct interaction between the central bank and economic agents via digital currency opens new avenues for monetary policy implementation. Programmability tools enable liquidity management without intermediaries, greater control over fund flows, and more targeted stimulation of economic activity. In the long term, this can enhance the effectiveness of the central bank’s monetary policy transmission mechanism and accelerate its impact on the real economy.

Increasing transaction volumes

Digital currency simplifies access to payment services and reduces the cost of transfers, including cross-border transactions. Increased speed and accessibility of payments create a multiplier effect across the economy.

Transaction security

The centralized platform of the national digital currency ensures guaranteed safety of users' funds, even in the event of a commercial bank failure, while the use of modern cryptographic methods and secure data transmission channels minimizes fraud risks.

Analyzing behavioral trends

Aggregated transaction data enables regulators to promptly assess changes in consumer sentiment and business activity. This creates a foundation for more accurate forecasting, timely responses to economic shocks, and greater adaptability of economic policy.

The Digital Tenge project is a strategic priority of the National Bank of Kazakhstan, aimed at strengthening the country's financial sovereignty and advancing the digital economy. CBDCs provide a foundation for innovation, shaping a more transparent, resilient, and technology-driven financial system.

The development of the CBDC is driven by several key factors. First, Kazakhstan tends to keep pace with global digital transformation in order to maintain its competitiveness on the international stage. Second, the digital tenge establishes a robust infrastructure for the development of new financial services due to its programmability. Another important aspect is the protection of the national monetary system: Kazakhstan's own digital currency will reinforce its financial independence and preserve control over monetary policy.

Zhanar Samaeva

Chairwoman of the Board National Payment Corporation of Kazakhstan

4 Impact of CBDC implementation on financial system participants

The introduction of a central bank digital currency affects all participants in the financial system. These changes extend beyond payment mechanisms to the overall architecture of interaction between the state, businesses, and citizens. Below is an overview of the impact of CBDCs on key market participants.

Individuals

1. Enhanced security of funds

One of the key benefits for individuals is increased security of savings and reduced risk of fraud. Funds held in CBDC accounts or wallets are stored directly on the central bank's platform, eliminating the risk of loss in the event of a commercial bank failure or disruptions in intermediary systems.

2. Reduced transaction costs

CBDCs can significantly reduce transaction costs, including fees for transfers and cross-border payments.

3. Improved access to financial services

CBDCs contribute to expanding financial inclusion, particularly in regions with limited internet access. Offline payment functionality enables users to conduct transactions without network connectivity, making financial services more available.

4. Additional benefits and incentives

During the adoption phase, incentive programs may be offered such as bonus programs, discounts, or lotteries. These mechanisms create behavioral impetus for using new instruments and accelerate the formation of digital habits among the population.

5. Payment automation

Technologies enable the embedding of conditions into the digital currency that determine how it can be spent or transferred. The programmability features of CBDCs enable automated settlements — for example, for utility bills or alimony payments. Such mechanisms simplify everyday financial transactions and increase the efficiency of personal financial management.

Nevertheless, the introduction of a national digital currency also carries certain risks for individuals: a reduction in the level of privacy, potential limits on fund holdings, dependence on technical infrastructure, and the risk of temporary unavailability of wallets during system failures. Additionally, a large-scale shift toward CBDCs may reduce the profitability of traditional savings instruments.

According to the Russian Public Opinion Research Center (VCIOM) survey "Digital Ruble: pros and cons" conducted in 2024, 31% of individuals expressed readiness to use a CBDC. In Canada, according to data from the Bank of Canada, half of respondents were ready to adopt a CBDC as of 2024. The level of acceptance of digital currency in Kazakhstan is slightly higher: in 2022, the results of a study on the introduction of the digital tenge showed that 60% of individuals were ready to use digital currency.

Merchants

1. Reduced fees

For businesses, one of the most tangible benefits is the reduction in acquiring costs. The absence of intermediaries between payer and payee enables lower-cost payments.

2. Transparency and security

Every transaction processed through a CBDC platform is recorded within a secure system, minimizing fraud risks and simplifying internal controls for businesses.

3. Simplified payment infrastructure

Merchants can accept payments directly without complex integration with multiple banks or processing centers. This is particularly important for small and medium-sized enterprises, which often have limited resources to maintain payment infrastructure.

4. Faster tax refunds

The programmability of a national digital currency enables automation of interactions with public finances — for example, facilitating automatic VAT refunds or execution of contracts within public procurement systems.

5. Offline payment capability

CBDCs allow businesses to conduct transactions even in the absence of an internet connection.

At the same time, businesses face certain **risks,** primarily related to increased regulatory oversight and dependence on the stability of the central bank's technical infrastructure.

Banks

1. New products development

Banks will be able to develop innovative solutions based on CBDCs, such as digital deposit products, smart contract-based services for corporate clients, and integrations with fintech platforms.

2. New payment Infrastructure

CBDC implementation drives the development of a new payment infrastructure, offering higher transaction speed and efficiency, reducing reliance on intermediaries, and lowering operational costs.

3. Increased competition and efficiency

CBDCs intensify competition among financial market participants, encouraging banks to revise pricing strategies and improve service quality.

4. Single point of integration with external services

Unlike traditional models, where each participant must independently adapt systems to new functionalities, a CBDC platform comes pre-equipped with core capabilities. By connecting to it, banks and other participants gain immediate access to updates and new features, including programmable payment scenarios and integration with external services. This reduces development costs and accelerates the rollout of innovative solutions.

However, CBDC implementation also entails several **risks** for banks. These include potential deposit outflows and reduced liquidity, particularly if the national digital currency is perceived as an alternative to traditional bank deposits. The potential reduction in fee income and the technological costs of integrating with the CBDC platform could also affect the stability of certain institutions.

Finally, disruptions in the central platform could cause reputational damage for banks participating in the ecosystem.

The overall impact of CBDC implementation will depend on how consistently and effectively regulators and market participants manage the risks outlined above. Potential benefits, including greater payment efficiency, inclusion, and technological development, could be undermined if insufficient attention is paid to cybersecurity, data privacy, and the financial system's ability to operate sustainably.

The introduction of the digital tenge is expected to enhance transparency in government financial flows, reduce the shadow economy, and improve tax collection. For citizens, this means greater security and accessibility of payments, lower transaction costs, including cross-border transactions, and the ability to conduct offline transactions. For businesses, this means lower fees, automated settlements via smart contracts and greater transparency of financial operations.

The selected two-tier model ensures a balance between innovation and stability: the NBK issues the digital tenge, while commercial banks and fintech companies provide services and payment solutions to end users. This creates conditions for competition, stimulates the development of new products, and strengthens trust in the financial system.

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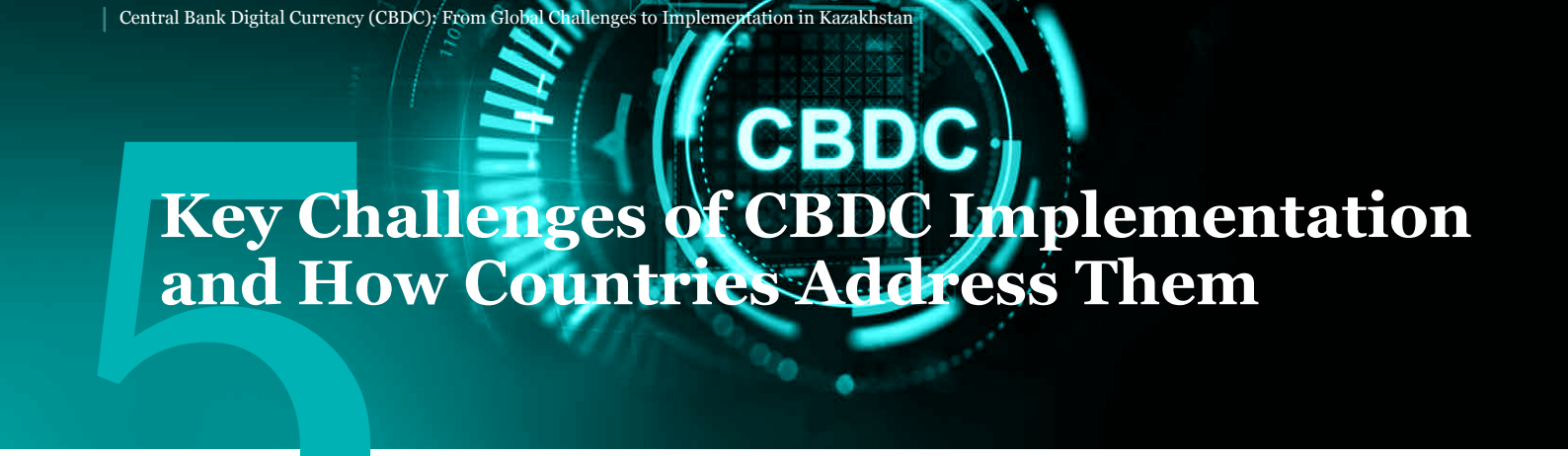


5 Key Challenges of CBDC Implementation and How Countries Address Them

Despite the wide range of potential benefits, CBDC implementation is associated with several challenges. These are both institutional and technological in nature, affecting the interests of individuals, businesses, banks, and regulators themselves.

The experience of countries that have already launched pilot projects and national initiatives confirms that the path toward mass CBDC adoption is accompanied by barriers that require a systematic approach to overcome. Below are the main challenges — how they manifest in different countries and what solutions regulators are finding for them.

1. Low awareness among the citizens and businesses

One of the most significant challenges faced by countries in implementing CBDCs is the low level of awareness among citizens and businesses regarding the goals, functions, and benefits of the new instrument. Although the concept of CBDCs is widely discussed at the global level, its substance often remains unclear to end users. In public perception, national digital currencies are frequently associated either with existing non-cash payment instruments or with cryptocurrencies, leading to confusion and reduced trust. A lack of understanding of how CBDCs can facilitate everyday transactions, enhance security, and reduce costs becomes a major barrier to adoption.

For instance, the Central Bank of The Bahamas, the first in the world to launch a CBDC (Sand Dollar) into circulation, identified insufficient user education as a key reason for low adoption rates. According to Bloomberg, half of Germany's population expresses concerns that the introduction of a digital euro would allow the state to track all user transactions — this is perceived as a threat to privacy and personal freedom. The World Bank highlights a similar issue in Middle Eastern countries, where limited awareness of digital innovations hinders the adoption of new payment technologies.

Country Approaches to Addressing the Challenge

Ambassador programs

To address this issue, central banks are developing targeted educational initiatives aimed at raising awareness. Among the tools used are **ambassador programs,** under which representatives of financial institutions and public organizations conduct seminars, consultations, and outreach events for citizens. In addition, digital formats are used: thematic portals, educational videos, and podcasts explaining how CBDCs work and demonstrating their everyday benefits.

This approach not only improves financial literacy but also fosters greater trust in regulatory actions. For example, the Central Bank of The Bahamas has placed significant emphasis on ambassador programs: its representatives actively engage with citizens, demonstrate the functionality of the Sand Dollar, and explain how it can simplify daily payments.

Incentive programs

One of the most notable examples is China, where lotteries were used in the early stages of e-CNY adoption: users were given the opportunity to win digital yuan, credited to special wallets and usable within a limited range of goods and services, without the option to convert into cash. At the same time, major platforms, including the ride-hailing aggregator DiDi, offered discounts for payments made in the national digital currency, thereby encouraging its usage. The Central Bank of Jamaica adopted a direct **incentive model:** the first 100,000 users who registered digital wallets received a bonus of 2,500 Jamaican dollars.

Integration into existing ecosystems

In China, e-CNY was embedded into leading payment platforms such as Alipay and WeChat Pay, making its use seamless and intuitive. In Sweden, testing of the e-krona also involves **integration** with commercial banking applications, such as Handelsbanken. In the Bahamas, a joint initiative between Island Pay and Mastercard was implemented in 2021, enabling the issuance of prepaid Sand Dollar cards and allowing purchases at any merchant that accepts Mastercard. This approach removes adoption barriers by allowing users to interact with CBDCs within familiar environments, significantly reducing resistance.

Social projects

In 2023, China launched an industrial park focused on developing the e-CNY ecosystem, including simplified payment solutions and testing of blockchain-based smart contracts. In Kazakhstan, a pilot project for automated school meal payments using the digital tenge platform, confirmed its convenience and transparency for both parents and educational institutions. In Russia, the digital ruble has been tested for scholarship payments, fine payments, and public transport cards top-ups, with plans to expand its use to social benefit disbursements.

China's experience clearly demonstrates the scale of potential impact. As of 2024, total transaction volume using e-CNY exceeded USD 1.4 trillion, the number of digital wallets surpassed 800 million, and the number of use cases exceeded 500. The digital yuan's share in the country's money supply reached 3%.

2.

High investment requirements for banks

A major challenge is the need for substantial investment in upgrading banking systems and integrating with national CBDC platforms. Banks are required to adapt internal processes, IT architecture, and infrastructure to operate within a unified digital environment. These costs become a critical factor, particularly for smaller banks and non-bank participants. At the same time, the potential savings from CBDC usage and reduced transaction costs are unlikely to fully offset the significant upfront capital expenditures in the early stages.

The International Monetary Fund notes that potential operational cost savings could be fully offset by the high costs of modernization and technical integration. According to estimates by Sberbank, total banking sector expenditures for integrating with the digital ruble platform could reach 30–50 billion rubles, while the costs of an individual credit institution are estimated at 200–300 million rubles. For small and medium-sized banks, such investments represent a critical barrier, while for larger institutions, they pose a risk to profitability.

Country approaches to addressing the challenge

To mitigate this problem, regulators are considering and applying several solutions.

White-Label solutions

One of the most promising approaches is the development by central banks of ready-to-use services that can be leveraged by financial intermediaries. This model enables banks to offer digital wallets and payment services based on existing infrastructure without incurring high costs for developing and testing their own systems. It lowers entry barriers and ensures a consistent quality standard. A similar approach can be observed in the crypto industry: in 2023, Circle, the issuer of the USDC stablecoin, introduced programmable wallet services that allow developers to easily integrate and manage crypto wallets within their applications.

Differentiated requirements

Another direction involves differentiating regulatory requirements across market participants. A uniform, rigid regulatory framework may prove overwhelming for smaller banks, whereas applying the principle of proportionality helps reduce this burden. Regulators could impose stricter requirements only on systemically important institutions. For example, within the implementation of the fast payment system PIX in Brazil, minimum quality standards for interfaces and user experience were established for all providers. This enabled smaller organizations to participate without excessive costs while maintaining a consistent level of usability and security for customers.

Cost reimbursement mechanisms

Another tool involves reimbursing part of the costs incurred by banks for development, integration, and other CBDC-related expenses through government support mechanisms. This may take the form of subsidies, tax incentives, or grants. A similar approach was successfully implemented in India during the rollout of the UPI instant payment system. Government subsidies enabled smaller banks and fintech companies to integrate into the system without excessive financial burden and played a critical role in its widespread adoption. Applying similar instruments in the CBDC context could stimulate broader participation and accelerate implementation.

Single central bank service

An alternative model involves the central bank offering a unified service for managing digital wallets and accounts. In this case, individuals and businesses gain access to CBDCs directly through the regulator's platform, while banks perform auxiliary functions — client verification under KYC procedures and redirecting users to the main platform. This architecture significantly reduces costs for banks, as it eliminates the need to create duplicate applications and infrastructure. However, this raises the question of the distribution of roles between the state and the commercial sector: direct interaction between customers and the central bank could change the traditional operating model of the financial market.

3.

Unclear benefits for the banking sector

For banks, CBDC implementation raises concerns about the sustainability of existing business models. Revenue streams from acquiring, transfer fees, and other transaction-based services may decline, leading to reduced overall profitability. At the same time, there is a risk of disintermediation: if individuals and businesses begin to hold funds directly in central bank digital currency, this could undermine banks' traditional funding base and limit their lending capacity.

> *Within the digital euro project, experts have expressed concerns that the new form of money could destabilize the Eurozone financial system due to the absence of clear mechanisms for compensating banks' lost income and managing liquidity. Similar views were raised during the development of the digital shekel in Israel, where experts pointed to the risk of changing the structure of banks' funding sources which could lead to higher credit costs.*

Country Approaches to Addressing the Challenge

Development of unique products

Global experience shows that regulators and banks are seeking solutions to balance interests. One such solution is the development of unique products based on CBDC functionality. Examples include short-term digital wallets for tourists, providing access to national currency without opening a bank account, and the implementation of self-executing transactions via smart contracts. These products enable banks to monetize new use cases and maintain customer value despite competition from the central bank.

Holding limits

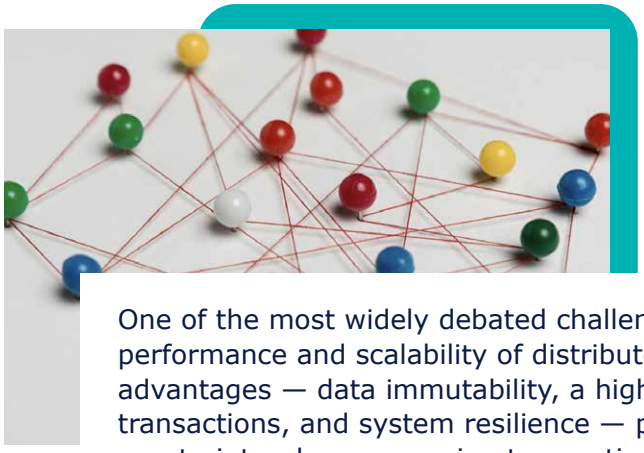
Introducing limits on CBDC balances helps prevent its use as a primary savings instrument and mitigates the risk of deposit outflows from banks. A common approach is the "reverse waterfall" mechanism, whereby a user's digital wallet is automatically funded from a bank account only for specific transactions, after which the wallet balance returns to zero.

Targeted promotion of CBDCs

At early stages of implementation, regulators may grant selected intermediaries exclusive rights to operate in specific market segments. For example, mobile network operators may receive priority access to provide services in rural areas where they have already established infrastructure. Banks that are among the first to integrate the CBDC into their service offerings gain a unique competitive advantage: the ability to attract new customers by providing them with access to innovative tools ahead of competitors.

Data-Driven analytics and upselling

Another promising area is the use of data-driven solutions. Integration with a CBDC platform allows banks to access customer transaction data (subject to user consent), enabling more accurate credit scoring, personalized offerings, and increased customer lifetime value. Banks can offer individual terms on deposits or loans tailored to specific consumer behavior patterns, enhancing customer loyalty and offsetting potential losses from reduced fee-based income.



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Technical and infrastructure challenges

One of the most widely debated challenges in CBDC implementation remains the limited performance and scalability of distributed ledger technology (DLT). Despite its clear advantages — data immutability, a high level of trust among participants, transparency of transactions, and system resilience — practical experience has shown that DLT faces constraints when processing transactions at the scale of a national economy. For retail CBDCs, designed to support millions of everyday transactions by individuals and businesses, performance becomes a critical factor.

Key challenges associated with DLT-based solutions include high resource requirements, complexity of integration with traditional banking systems, the risk of irreversibility of erroneous transactions, and, most importantly, limited scalability to the level of national payment systems. Unlike non-DLT platforms, distributed systems require consensus across multiple nodes, which significantly slows down transaction processing and increases infrastructure load. This makes the use of DLT as the foundation for retail CBDCs more difficult.

Reports by the Bank for International Settlements (BIS) emphasize that distributed ledger systems inherently reduce transaction processing speed due to the need to achieve consensus across network nodes. This inevitably increases transaction times compared to centralized systems.
Traditional blockchain architectures are not yet capable of delivering the speed and resilience required to process millions of transactions per second, which is necessary for the functioning of a national economy. Maintaining high performance, fault tolerance, and operational continuity requires substantial resources and new technological approaches.

Country approaches to addressing the challenge

In response to the low performance of DLT systems, central banks are seeking solutions that preserve the advantages of distributed ledgers while simultaneously ensuring operational scalability.

Hybrid model

In response to these challenges, central banks are increasingly exploring alternative architectures that combine the strengths of both distributed and centralized technologies. In a hybrid model, DLT may be used as a component to enhance trust and reliability of specific system elements, while core transaction processing is built on centralized infrastructure.

This approach has been tested in Sweden: during the e-krona pilot on the Corda R3 platform, the Riksbank concluded that hybrid architectures may be necessary to achieve the required level of scalability. Similar discussions are underway within the digital euro project, where the European Central Bank is evaluating scenarios that combine distributed ledgers with centralized databases, aiming to balance transparency and trust with efficiency and speed of traditional systems.

Distributed databases, but non DLT

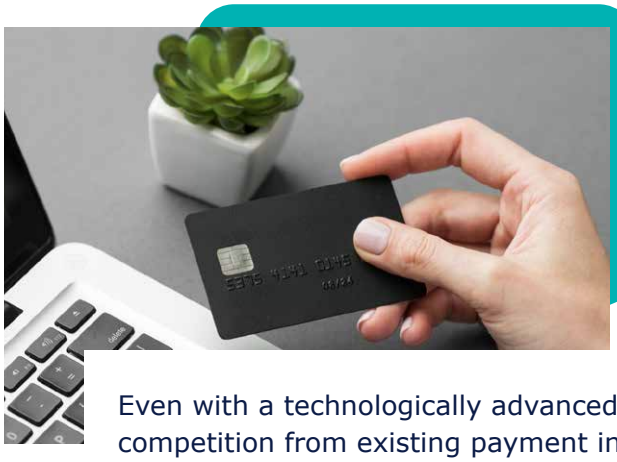
In a number of jurisdictions, the possibility of using distributed databases is being explored. These solutions retain many of the advantages of DLT (distributed architecture and fault tolerance) but do not require the use of public consensus algorithms. In such systems, all nodes operate within a single secure perimeter of the central bank, and state changes are validated not through a decentralized mechanism, but through regulated verification procedures and centralized control policies.

Data replication follows predefined scenarios, ensuring a balance between security and performance. These solutions can achieve performance levels comparable to traditional high-load systems. One technological example is YugabyteDB, a distributed SQL platform that combines the scalability and fault tolerance of NoSQL systems with the manageability of relational databases.

Government-to-Business (G2B) use cases for DLT

In parallel, the strategic possibility of shifting the focus of DLT applications from high-volume retail use cases to the Government-to-Business (G2B) segment is also being discussed. Unlike high-volume C2B or B2C transactions, operations between government and businesses are less frequent but require a high level of trust, transparency, and data immutability. These are precisely the characteristics enabled by DLT.

Examples of such use cases include: automation of tax settlements, VAT refunds, public procurement processes, and the use of smart contracts in government subsidy programs. In Kazakhstan, as part of the Digital Tenge project, pilot scenarios are being explored for automated VAT calculation and payment, fund holding for livestock purchases, as well as marking of budget funds to ensure targeted use under government contracts. In China, businesses are already able to pay taxes and customs duties using e-CNY, demonstrating the practical potential of G2B scenarios based on digital currencies.



5.

Competition from traditional payment instruments

Even with a technologically advanced model, national digital currencies face strong competition from existing payment instruments. In countries where traditional tools — bank transfers, payment cards, or instant payment systems – already offer high levels of convenience, speed, and accessibility, user motivation to switch to a new format remains limited.

China's experience demonstrates that the launch of a CBDC did not necessarily replace existing payment services such as Alipay and WeChat Pay, which remain the primary and most convenient payment methods for users. A similar trend is observed in India, where the digital rupee pilot has shown limited interest from both individuals and businesses, as existing payment systems, such as the instant payment system UPI, already fully meet users' everyday needs. The World Bank notes that in the Middle East and North Africa, the situation is further complicated by fragmented payment markets: competition between CBDCs and commercial money could lead to conflicts and additional risks to banking system stability, including potential deposit outflows.

Country approaches to addressing the challenge

Targeted use of funds

One of the most promising areas is the targeted use of funds. The ability to mark funds and track their spending within specified limits opens up fundamentally new mechanisms for fiscal policy and corporate finance. In Kazakhstan, a mechanism for automated VAT refunds is already being tested: the 'hermetic' nature of digital transactions allows refunds to be made without additional checks and in the shortest possible time. In Russia, an experiment on marking budget funds using the digital ruble is planned for 2025, which should ensure their targeted spending and full traceability.

Similar initiatives are being developed in India, where the digital rupee will be used for targeted government payments. These examples show that CBDCs can not merely duplicate the functions of existing payment systems, but create fundamentally new tools for managing cash flows.

Smart contracts

The second promising area is smart contracts, which enable the automated execution of financial obligations without intermediaries. International projects demonstrate a wide range of applications, from cross-border payments to the automation of corporate procurement. For example, the Project Icebreaker explored the use of Hashed Timelock Contracts (HTLC) to synchronize settlements across different CBDC platforms. In the UAE, the development of the Digital Dirham includes testing programmable payment scenarios such as conditional transfers, multi-stage transactions, and scheduled automatic payments.

In Kazakhstan, solutions are being considered for the agricultural sector, where the holding of funds ensures that payment is made only after confirmation of the delivery of livestock. Such mechanisms fundamentally change the architecture of transactions and reduce the role of intermediaries, providing additional value for businesses.

PvP / DvP cross-border payments

Particular attention is being paid to the development of payment mechanisms based on payment versus payment (PvP) and delivery versus payment (DvP) principles for cross-border settlements. Their primary objective is to eliminate counterparty risk by synchronizing the transfer of assets and payments. Project mBridge, involving the central banks of Hong Kong, China, Thailand, and the UAE, represents one of the largest experiments in this area. Its goal is to establish a multi-currency platform based on CBDCs and DLT technologies, enabling fast and secure international settlements.

In Saudi Arabia and the UAE, the Aber project has also explored the use of digital currencies for cross-border transactions. Meanwhile, France, Germany, and Singapore are collaborating on the Rialto project to study integrating CBDCs with decentralized finance solutions to make international payments more efficient.

Offline payments

Offline payments represent a significant competitive advantage of CBDCs, enabling transactions without internet connectivity. This is particularly important for regions with underdeveloped digital infrastructure. Various formats are being explored, ranging from NFC-based payments and hardware devices to solutions that allow multiple transactions to be executed autonomously over a specified period. Some pilots include scenarios with preloaded cards, where the balance is recorded locally and transactions are confirmed offline.

Anonymous payments

Transaction privacy remains a critical topic. Unlike commercial payment instruments, national digital currencies enable the implementation of "controlled anonymity" models. The European Central Bank, as part of the digital euro project, has stated that it will not have access to user balance and transaction data: such information will remain with commercial banks acting as intermediaries. The Bank of Israel is considering a similar approach, preventing direct identification of transactions by the regulator.

China has a differentiation model: anonymity is provided for small transactions in e-CNY, while larger transactions require disclosure. These approaches help maintain a balance between citizens' privacy requirements and the need for regulatory oversight and financial stability.

Instant payments

CBDCs can fill gaps where instant payment infrastructure is absent. In countries where traditional systems do not support 24/7 instant transactions, national digital currencies become a key driver of modernization. In Jamaica, Jam-Dex enables real-time payments 24/7 with minimal costs. In The Bahamas, the Sand Dollar compensates for the lack of instant payments infrastructure by offering free and instant transfers. In the Eastern Caribbean Currency Union, DCash has become the only instrument providing 24/7 instant payments for both individuals and businesses.

6 Economic Impact of CBDC for Kazakhstan

The introduction of CBDC creates strategic opportunities for Kazakhstan to enhance the transparency, efficiency, and resilience of the national financial system. The digital tenge is viewed not merely as a technological innovation, but as a foundational infrastructure for further digitalization of the economy, deepening financial inclusion, and strengthening trust in public institutions.

Impact on the government and the economy

For the government, the primary benefit lies in increased transparency of financial flows. The use of "programmable money" technologies enables end-to-end tracking of funds across the entire transaction chain, ensuring control over targeted budget spending and reducing corruption risks. Government agency gain a powerful monitoring tool that enhances the effectiveness of financial oversight and reduces the likelihood of fraud and money laundering.

For the economy as a whole, a digital currency can act as a catalyst for the development of cashless payments and foster a more competitive and innovation-driven financial sector. Expanding access to digital financial services facilitates the inclusion of a broader segment of citizens and businesses, directly contributing to increased financial inclusion.

CBDC also creates conditions for diversifying payment infrastructure, reducing dependence on external settlement systems and strengthening the country's financial sovereignty. An additional impact is linked to the development of new services based on the digital tenge. Programmability and interoperability with other platforms enable the creation of ecosystem-based solutions – from automated settlements within government contracts to targeted social payments and innovative corporate payment products. Finally, the use of CBDC in cross-border transactions can reduce costs and processing times for international transfers, which is particularly important for a Kazakhstan as a country with a developed export-import sector and active migration dynamics.

The digital tenge will become a reliable instrument for long-term economic modernization, supporting Kazakhstan's technological development and its integration into the global financial space.

By 2024, the share of the shadow economy in Kazakhstan decreased to 16.7% of GDP, driven by the adoption of digital technologies, including the use of artificial intelligence for data analysis. CBDC will further boost financial transaction transparency and automate tax accounting, making tax evasion increasingly difficult.

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Key Use Cases

Chairwoman

The most promising use cases involve tax process optimization, budget expenditure management, and payment automation.

Marking and accelerated VAT refunds

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The use of marked digital tokens enables automatic verification and allocation of VAT payments, ensuring faster tax collection and simplifying the refund of overpaid amounts. This approach also allows excess VAT to be automatically offset against future tax liabilities, improving the efficiency of interactions between businesses and the government.

Targeted use of budget funds

2

In this scenario, the digital tenge is marked with specific receivers and spending purposes. Any attempt to use such funds outside designated parameters is automatically blocked by the system, while government authorities gain full visibility over the transaction chain. This solution ensures transparency of public spending, improves budgetary efficiency, and reduces the risk of corruption.

Automation of government subsidies

3

The digital tenge system enables "smart" management of government subsidies. Funds are held until the target conditions are met, then automatically transferred to the receiver. This approach minimizes errors, prevents misuse, and ensures transparent fund distribution among support programs participants.

Automation of payments upon delivery confirmation

4

The use of fund "holding" mechanisms allows funds to be locked in the buyer's wallet until delivery is confirmed. Once confirmation is received, funds are automatically transferred to the seller. This solution reduces the risk of non-performance and strengthens trust between counterparties.

In designing the digital tenge, Kazakhstan relied on leading international practices while adapting them to its own economic and technological context. This approach enabled the country not merely to adopt foreign experience, but to develop a unique CBDC framework aligned with domestic market needs and national economic priorities.

The digital tenge project has evolved in stages – from piloting basic use cases to creating a comprehensive ecosystem that integrates government authorities, banks, and the corporate sector. Today, particular emphasis is placed on targeted use of budget funds, automation of VAT refunds, and transparent management of public expenditures. These solutions can significantly improve the efficiency of financial management and trust in public institutions.

7 Conclusion

Analysis of global CBDC implementation demonstrates that success depends not only on technological design, but also on a state`s ability to build a sustainable ecosystem of interaction among market participants. CBDCs become a tool that unite innovation with public policy, enhancing the efficiency of financial flows and strengthening trust in institutions.

Kazakhstan's digital tenge experience proves that a consistent, phased approach focused on real economic needs can turn a CBDC from an experiment into a core component of the national financial system. In the long term, the digital tenge could become a model for other countries seeking stronger financial sovereignty and a sustainable digital economy.

Kazakhstan has moved from the experimental stage to a sustainable phase of developing the digital tenge — an instrument that creates transparency of financial flows, stimulates innovation, and opens up new opportunities for effective interaction between the state, business, and citizens. This reflects a mature and well-considered approach to CBDC development, aimed at maximizing alignment with the needs of the domestic market and the stability of the financial system.

When CBDC design and implementation successfully balance the interests of the government, businesses, and citizens, account for regulatory and technological risks and adapt architecture to national economic specifics, financial system participants gain.

The government benefits from increased transparency and control over financial flows; businesses from reduced transaction costs and new automation opportunities; and citizens from improved accessibility and speed of financial services. This balance transforms CBDC from a mere digitalization tool into a driver for sustainable and inclusive economic development.

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8 Appendix

Glossary

AML / CFT	Anti-Money Laundering / Countering the Financing of Terrorism
Blockchain	A type of distributed ledger technology where transactions are grouped into blocks and secured using cryptography
C2B / B2C – Consumer-to-Business / Business-to-Consumer	Consumer-business interaction models
CBDC	Central Bank Digital Currency
Controlled anonymity	A model where small transactions remain private, while larger transactions are subject to regulatory oversight
Data-driven analytics	An approach in which decisions are made based on the analysis of large volumes of data
DCash	A digital currency issued by the Eastern Caribbean Central Bank
Digital Dirham	The central bank digital currency project of the UAE
Disintermediation	The removal of intermediaries from financial processes, for example, when users interact directly with a CBDC platform
DvP – Delivery versus Payment	A settlement model in which the transfer of an asset occurs simultaneously with payment
DLT – Distributed Ledger Technology	A database with synchronously replicated copies distributed across multiple network nodes
Financial inclusion	The expansion of access to financial services for individuals and businesses

Funds holding	A mechanism for temporarily locking funds until specified conditions are met, such as confirmation of delivery
G2B – Government-to-Business	Interactions between government entities and businesses
HTLC – Hashed Timelock Contract	A type of smart contract that ensures execution of a transaction within a specified timeframe
Jam-Dex – Jamaica Digital Exchange	The digital currency of Jamaica Central Bank
KYC – Know Your Customer	A procedure for customer identification in financial institutions
Programmability of money	The ability to define conditions for the use of funds, including purpose, timing, and restrictions
PvP – Payment versus Payment	A settlement model in which asset transfer and payment occur simultaneously, eliminating counterparty risk
Reverse waterfall	A mechanism where a digital wallet is automatically funded from a bank account only for specific transactions
Smart contract	A self-executing digital contract that automatically enforces terms when predefined conditions are met
UPI – Unified Payments Interface	An instant payment system in India
Upselling	The practice of offering customers higher-value or additional products based on behavioral analysis
VAT	Value Added Tax
White-label solutions	Ready-made technological products that banks and fintech companies can deploy under their own brand

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Methodology

The study was conducted by Axellect in collaboration with the National Payment Corporation of the National Bank of the Republic of Kazakhstan.
The analytical work was based on international sources, including reports from the Bank for International Settlements, the International Monetary Fund, and central banks engaged in CBDC initiatives. In addition, expert consultations were held with representatives of Kazakhstan's financial sector.
This approach enabled the integration of global experience with local insights, providing a comprehensive understanding of the key challenges and prospects of CBDC implementation.
The data presented in the study regarding CBDC developments across countries are current as of September 1, 2025.