FEDERAL RESERVE BANK *of* NEW YORK

New York Innovation Center

PROJECT CEDAR

Phase One Report

FALL 2022

ONYIC

Overview

Project Cedar is the inaugural project of the New York Innovation Center (NYIC). The NYIC, a part of the Federal Reserve Bank of New York (New York Fed), bridges the worlds of finance, technology, and innovation. Established in partnership with the Bank for International Settlements Innovation Hub (BISIH), the NYIC generates insights into high-value central bank-related opportunities through technical research, experimentation, and prototyping, to drive advancements in central banking and enhance the functioning of the global financial system. In support of these objectives, the NYIC aims to advance research regarding wholesale central bank digital currency (wCBDC) within the U.S. context.

Project Cedar is a multiphase research effort to develop a technical framework for a theoretical wCBDC, conducted by the NYIC in conjunction with subject matter experts throughout the New York Fed. This research will explore fundamental design choices and modular technical features.

A wCBDC is a specific type of digital bank reserve held at the central bank that could be used by financial institutions to effect wholesale transactions, such as interbank payment clearing and settlement. Wholesale CBDCs have the potential to drive improvement in the larger wholesale market by facilitating the safe, rapid, and efficient transfer of central bank liabilities. Enabling technology, such as distributed ledgers, could provide benefits

such as transparency, resiliency, and programmability. Central bank liabilities that can be transferred through these systems in the form of wCBDC have the potential to drive enhancements to existing payments infrastructure and spur future payments innovation. Phase I of the Project Cedar experiment examined the potential application of distributed ledger technology (DLT), specifically blockchain, to enhance the functioning of wholesale cross-border payments.

Phase I was a successful twelve-week undertaking demonstrating the viability of this technology to enable instant and atomic settlement in a simulated foreign exchange (FX) spot transaction between the New York Fed and counterparties across separate, homogeneous ledgers. These objectives were selected both because they address known issues of speed and access mechanisms in wholesale cross-border transactions and because they represent core value propositions of DLT in a wCBDC use case.[1]

Under simulated test scenarios based on market throughput estimates, FX spot trades were atomically settled in under ten seconds, validating the project objectives of enabling instant and atomic settlement using DLT while also revealing promising applications for blockchain in wholesale payments and presenting questions for future research.

This Phase I report aims to contribute to a broad and transparent public dialogue about CBDC from a technical perspective. The report is not intended to advance any specific policy outcome, nor to signal that the Federal Reserve will make any imminent decisions about the appropriateness of issuing a retail

[1] See: "Enhancing Cross-Border Payments: Building Blocks of a Global Roadmap", Bank for International Settlements, Committee on Payments and Market Infrastructures, July 2020

or wholesale CBDC, nor to offer an indication of how one would necessarily be designed.

Problem Space

Cross-border payments are financial transactions conducted between central banks, private sector banks, corporations, and others. In these transactions, the payer and recipient are based in separate jurisdictions. The payment can be categorized as wholesale (e.g., payments between financial institutions, governments, official institutions, and large nonfinancial companies) or retail (e.g., payments between individuals and businesses). The NYIC's CBDC research focuses exclusively on the wholesale market.

Foreign exchange spot trades are among the most common wholesale cross-border transactions. These transactions can be conducted bilaterally or multilaterally between counterparties such as central banks and private sector financial institutions. The FX market is the largest wholesale market in the world, with daily turnover of over $7 trillion.[2] Given the size and breadth of this global market, the potential impacts of technological innovation on its operations and processes are substantial.

Currently, cross-border transactions function well, but there are opportunities for improvement. In general, it takes around two days for an FX spot transaction to settle. During these two days, payment senders and recipients are exposed to settlement, counterparty, and credit risk which, among other things, can hinder

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2 See "Triennial Central Bank Survey: Global Foreign Exchange Market Turnover in 2022", Bank for International Settlements, Monetary and Economic Department, October 2022

an institution's ability to readily convert its assets into cash. Additionally, the proportion of transactions settled on a payment-versus-payment (PvP) basis has fallen below 40 percent in recent years, increasing settlement risk exposure across the FX market.[3]

Cross-border settlement of FX spot trades is a common starting point for wCBDC research, as central bank liabilities are the core settlement asset in these types of transactions. Furthermore, FX spot transactions underpin a large portion of the wholesale payments market and represent a known problem space for issues of access and speed of settlement. Enabling safe, fast, low-cost, transparent, and accessible wholesale cross-border transactions is critical to the functioning of the global economy.

Use Case

An FX spot transaction was selected as the use case for the Phase I experiment for several reasons:

- **Asset type:** Central bank liabilities (e.g., USD and other foreign currencies) are the only asset types involved in this type of transaction, allowing for the simulation of exchange of a hypothetical USD wCBDC against a hypothetical foreign wCBDC.

- **Market structure:** The spot exchange of one currency for another is the foundation of the FX market. This type of trade is often one segment of a

3 See "Consultative Report: Facilitating Increased Adoption of Payment Versus Payment (PvP)", Bank for International Settlements, Committee on Payments and Market Infrastructures, July 2022

broader international financial transaction that may involve other asset types as well. Demonstrating the viability of this type of transaction therefore has implications for a significant portion of the wholesale cross-border market.

- **Complexity:** A spot transaction is a relatively simple transaction, as FX rates are agreed upon at the start of the transaction. This allows for a narrow scope demonstrating the value of the technology without requiring development of some advanced features.

The New York Fed is an active participant in the FX market, executing transactions on behalf of the U.S. Treasury Department and Foreign and International Monetary Authorities that maintain accounts with the Federal Reserve.

To further understand the context for FX spot transactions at the New York Fed and to validate the working hypothesis and potential solution concept, the NYIC team conducted interviews with a range of market participants. Ultimately, these interviews validated the hypothesis that settlement speed and access to PvP mechanisms are key issues in wholesale cross-border payments. Based on this research, a future state solution should enable atomic settlement, access to a wider range of counterparties, and settlement taking place faster than T+2.

Experiment Design

Based on findings regarding the current state process, a problem statement, hypothesis, and associated assumptions were developed for Phase I of Project Cedar:

PROBLEM STATEMENT

Wholesale cross-border payments can be slow and limited in access.

HYPOTHESIS

There is a distributed ledger technology solution for wholesale FX settlement that results in instant and atomic settlement in which a wCBDC is the settlement asset.

CRITICAL ASSUMPTIONS

1. Issues of speed are rooted in the settlement stage of a current state FX spot transaction.
2. Current delays in settlement times are driven in part by manual validation of the transaction.
3. Current limitations in access are driven in part by counterparty risk.
4. Barriers to instant and atomic settlement in the current state can be removed through a technology solution.
5. A low-fidelity wCBDC prototype can be developed to demonstrate a significant reduction in settlement time.

Phase I of Project Cedar was designed to test the hypothesis and critical assumptions above and to reveal insights related to the wCBDC research interests of the NYIC. The following objectives were set to meet these goals:

SIMULATE 1

Simulate an FX spot transaction using a wCBDC prototype demonstrating:

- **Instantaneous settlement**

  Defined as fewer than 30 seconds.

- **Atomic settlement**

  Defined as payment-versus-payment settlement in which both legs of the transaction are settled simultaneously or not at all.

- **Interoperability**

  Defined as interaction across separate, homogeneous ledgers to settle the transaction.

CAPTURE 2

Capture performance data to determine success and establish a benchmark for future research.

IDENTIFY 3

Identify additional questions and considerations for future wCBDC design work.

The scope of Phase I was tailored to demonstrate the key objectives of instant and atomic settlement in a viable prototype. Phase I also laid the foundation for future research into interoperability by simulating a multi-ledger ecosystem across homogeneous ledger technology. To focus on these foundational objectives, several important research topics were designated as out of scope for Phase I, including scalability, privacy, and programmability. Additionally, non-settlement processes, such as market making and AML/OFAC, were assumed to take place off-ledger and were abstracted for the purposes of the prototype.

Solution Concept

Core to Project Cedar's solution is the ledger infrastructure of the experiment—a bespoke system leveraging ideas from existing digital currency technologies to provide functionality relevant for a wCBDC. Phase I of Project Cedar was designed around a multi-ledger construct in which each currency was maintained on a separate ledger, operated by its respective simulated central bank. Phase I used this design to enable instant and atomic settlement of an FX spot transaction.

The solution design in Project Cedar Phase I represents a starting point for future wCBDC research. The Phase I prototype included design choices such as a permissioned blockchain network, an Unspent Transaction Output (UTXO) data model, and Rust as the primary programming language. Design choices made for Phase I will be tested against alternatives in future phases and do not represent conclusive design choices of the NYIC or of any future U.S. CBDC.

The table below outlines key components of the Phase I prototype design:

PROGRAMMING LANGUAGE	Rust
LEDGER DATA	Unspent Transaction Output (UTXO)
PERMISSION STRUCTURE	Permissioned
SINGLE-LEDGER VS. MULTI-LEDGER	Multi-ledger
CONSENSUS PROTOCOL	Proof-of-Authority
ASSET TRANSFER MECHANISM	Hash Time Lock Contracts (HTLCs)

Results

Test results from the experiment revealed that the blockchain-enabled payments system settles transactions in fewer than ten seconds on average and that throughput across the system increases as additional currencies are included. This indicates that a modular ecosystem of ledgers has the potential for continued scalability, and that DLT could enable atomic settlement faster than the current industry standard of two days, should processes that were abstracted in the Phase I prototype, such as compliance checks and market making, be similarly streamlined.

The table below highlights key results across three test scenarios. The scenarios were designed to assess the system's performance as it scaled to include a broader number of simulated actors in the ecosystem. Each test scenario comprised a specific number of Currencies (C), Observers (O), and Participants (P), as detailed below.

Key Results for Phase I

TEST SCENARIO			CROSS-CHAIN SWAP LATENCY[4] (in seconds)		CROSS-CHAIN SWAPS (per second)	
C	O	P	Mean	99th percentile	Mean	Peak
2	2	4	9.05	14.54	10.91	33.27
4	4	8	8.52	12.84	18.78	47.20
8	8	16	8.96	15.86	37.53	98.93

In addition to meeting the goals of instant and atomic settlement, Phase I successfully established a basis for future NYIC research into potential advancements of the systems that move money and other financial assets between banks and financial institutions. The data produced in this phase represent a benchmark for future testing. Importantly, the Phase I prototype also demonstrated a successful guide for how wCBDC may be exchanged in a multi-ledger ecosystem. Future research focused on interoperability across a heterogeneous mix of DLT stacks will evolve these findings.

[4] Cross-Chain Swap Latency is defined as the time between transaction broadcast and finalization.

Looking Ahead

Phase I of Project Cedar provided crucial input toward the NYIC's central aim of technical research on wholesale CBDC in the U.S. context. The work also highlighted several opportunities for future research by the NYIC, including ledger design, interoperability, security, and more. Research across these areas will help inform potential technical design choices and considerations.

As part of its continued wCBDC research, the NYIC will next explore questions related to interoperability and ledger design, including how to achieve concurrence and certainty in settlement across different blockchain based payments systems.