BIS Innovation Hub

Project Rialto

Improving instant cross-border payments using central bank money settlement

Interim report

February 2025

BANCA D'ITALIA EUROSISTEMA

BANK NEGARA MALAYSIA CENTRAL BANK OF MALAYSIA

BANQUE DE FRANCE EUROSYSTÈME

MAS Monetary Authority of Singapore

© Bank for International Settlements 2025.
All rights reserved.
Limited extracts may be reproduced or translated provided the source is stated.

www.bis.org
email@bis.org

Follow us

Executive summary

The retail cross-border payments market is valued at more than $800 billion of transactions per year, and is growing. Despite this, retail cross-border transactions lag domestic ones in terms of cost, speed, access and transparency because of the complex processes they involve. This complexity comes from a number of factors, including compliance, market infrastructure, foreign exchange (FX) services and settlement assets and procedures.

Project Rialto targets FX- and settlement-related frictions in retail cross-border payments. The project's goal is to develop a proof of concept to demonstrate the technical feasibility of retail cross-border payments using interlinked instant payment systems together with an automated FX wholesale conversion layer that allows the use of central bank money (CeBM) as a safe settlement asset.

Project Rialto has two main contributions. First, it will show how an automated FX conversion layer with settlement in CeBM can help simplify the payment chain and reduce a number of risks such as liquidity, credit and settlement risks, potentially reducing the cost of retail cross-border payments. Second, the project will combine instant payment systems with a next generation tokenised market infrastructure for CeBM settlement. Such integration raises some specific challenges and design considerations, which will be addressed in the development phase and form an integral part of the project's contributions to improving cross-border payments.

This report outlines the main features and challenges in the retail cross-border payments market, identifying the main policy and technical aspects to be considered in Project Rialto. Details of the proof of concept, as well as findings from the experiment, will be described in the final project report.

Project Rialto is a collaboration between the BIS Innovation Hub Eurosystem and Singapore Centres, the Bank of France, the Bank of Italy, Bank Negara Malaysia (the Central Bank of Malaysia) and the Monetary Authority of Singapore.

List of abbreviations and acronyms

AMM	Automated market maker. Decentralised exchange using a bonding curve and a liquidity pool to price and exchange tokenised assets
AML/CFT	Anti-money laundering and combating the financing of terrorism
API	Application programming interface
CBDC	Central bank digital currency
CeBM	Central bank money
CLS	Continuous linked settlement
CoBM	Commercial bank money
CPMI	Committee on Payments and Market Infrastructures
DeFi	Decentralised finance
DEX	Decentralised exchange
DLT	Distributed ledger technology
DvP	Delivery versus payment
ECB	European Central Bank
EU	European Union
EUR	Euro
FSB	Financial Stability Board
FX	Foreign exchange
Gas fee	A fee required to successfully conduct a transaction or execute a contract on a blockchain platform
GDP	Gross domestic product
IPS	Instant payment system
Liquidity pool	A liquidity pool (LP) is a smart contract with the ability to hold and transfer tokenised assets based on a pre-defined logic
LOB	Limit order book
On-chain, off-chain	On-chain (off-chain) usually refers to data that is stored and processed on (or outside) a blockchain
PoC	Proof of concept
PSP	Payment service provider
PvP	Payment versus payment
RTGS system	Real-time gross settlement system
SGD	Singapore dollar
Smart contract	A smart contract is a program stored on a distributed ledger technology (DLT) platform that executes based on a pre-defined logic
Tokenisation	The process of recording claims on real or financial assets that exist on a traditional ledger onto a programmable platform
wCBDC	A wholesale CBDC (wCBDC) is a CBDC available to commercial banks and other licensed financial institutions

Table of contents

Executive summary 3

List of abbreviations and acronyms 4

1. Introduction 6

2. Project overview 7
2.1. Proposed approach 8
2.2. Experiment scope and landscape 9

3. Main use case 11

4. Financial market infrastructures 13
4.1. Interlinked instant payment systems 13
4.2. Multi-currency clearing and settlement mechanisms 14
4.3. Programmable digital asset systems 14

5. Settlement assets 15
5.1. Role of commercial bank money 15
5.2. Role of central bank money 16
5.3. Tokenised CoBM and CeBM 17

6. FX market-making approaches 19
6.1. Automated market makers 19
6.2. Decentralised order books 20
6.3. Hybrid DEX and aggregators 20

7. FX services in technological experiments 21

8. Remaining challenges 24

9. Conclusion and next steps 25

Project participants and acknowledgments 26

References 28

1. Introduction

Improving cross-border payments is an international policy target for the G20. Achieving cheaper, faster, more transparent and more accessible cross-border payments would have widespread benefits for citizens and economies worldwide, while also supporting economic growth, international trade, global development and financial inclusion (FSB (2020)). The policy implications of undertaking such efforts can be valued at several billion dollars, given the size of the global cross-border payments market (FSB (2021); World Bank (2023)). In the European Union, the European Commission has stressed the importance of improving the efficiency of cross-border payments in its capital markets union action plan (European Commission (2020a)) and its retail payments strategy (European Commission (2020b)).

Previous literature on financial market infrastructure and payment systems has identified the interlinking of instant payment systems (IPS) and the interoperability of central bank money arrangements as the most promising methods to make cross-border payments immediate, cheap, universal and settled using a safe settlement medium (Auer et al (2021); Boar et al (2021); CPMI (2022); Bindseil and Pantelopoulos (2022); Aurazo et al (2024)).

While previous technical experiments looked at these methods separately, Project Rialto (BISIH (2024)) will experiment with how they can interact with one another to help improve cross-border payments. More specifically, the project will explore how to improve instant cross-border payments using wholesale central bank money settlement on a tokenised platform. In outlining the main features and challenges in the retail cross-border payments market, this report identifies the main policy and technical aspects to be considered in Project Rialto.

2. Project overview

Project Rialto builds on previous work conducted by the BIS Innovation Hub focused on cross-border payments. The project's goal is to develop a novel solution for cross-border payments with central bank money (CeBM) settlement and an automated foreign exchange (FX) conversion layer. To this end, the project will develop a modular FX component that will be used to test cross-border transactions using simulated interlinked IPS.

The hypothesis to be tested is whether a transnational tokenised network might enable the exchange of currencies at the time a cross-border payment is being made, thus simplifying the currency trading and conversion processes. The use of domestic IPS could ensure speed and reachability for all payment service providers (PSPs) while the use of tokenised CeBM as a safe settlement asset could mitigate liquidity, credit and settlement risk, and streamline the payment chain, potentially driving down the overall cost of cross-border transactions.

The contribution of Project Rialto is twofold. First, the project will show how an automated FX conversion layer with settlement in CeBM can help simplify the payment chain and reduce a number of risks such as liquidity, credit and settlement risks (Box A), potentially reducing the cost of retail cross-border payments. Second, Project Rialto will combine instant payment systems with a next-generation market infrastructure for CeBM settlement. Such integration raises some specific challenges and design considerations, which will be addressed in the development phase and form an integral part of the project's contributions to improving cross-border payments.

Overview of FX related risks in cross-border transactions – Box A

Liquidity risk:
The risk that a counterparty, whether a participant or other entity, will have insufficient funds to meet its financial obligations as and when expected, although it may be able to do so in the future.

Example:
A PSP is unable to meet its cross-border payment obligations in a timely manner due to illiquidity in a specific currency corridor.

Rialto:
By providing access to CeBM and instant FX services when a payment is being made, the innovative settlement layer proposed in Project Rialto can reduce this risk.

Credit risk:
The risk that a counterparty, whether a participant or other entity, will be unable to meet fully its financial obligations when due, or at any time in the future.

Example:
In the event of a default or non-performance of one party to the cross-border payment, a PSP may be forced to return to the market to obtain the currency it had expected to receive, leading to a larger risk of exposure.

Rialto:
By allowing a payment to be settled in CeBM and provided funds are available in the innovative settlement layer, the approach proposed in Project Rialto can reduce this risk.

Settlement risk:
The risk of loss when a party in an FX transaction pays the currency it sold but does not receive the currency it bought.

Example:
Existing payment versus payment (PvP) settlement arrangements are unavailable, or unsuitable for certain trades, or market participants find them too expensive (see BIS (2022), Glowka and Nilson (2022) and CPMI (2023)).

Rialto:
By integrating IPS with an innovative settlement layer, the approach proposed in Project Rialto can provide access to PvP settlement for retail transactions and reduce this risk.

2.1. Proposed approach

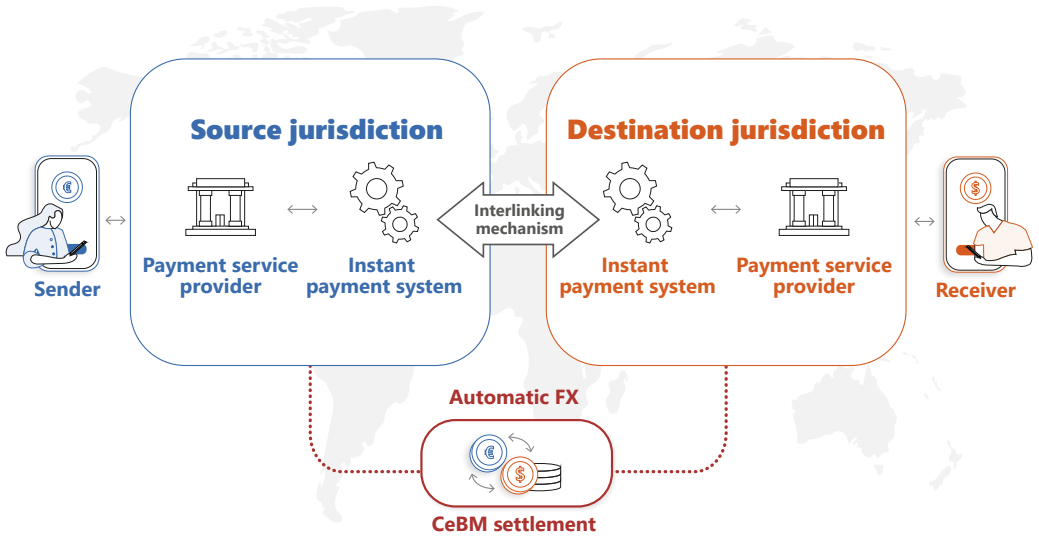
Project Rialto aims to demonstrate the technical feasibility of retail cross-border payments using interlinked IPS together with an automated FX wholesale conversion layer that allows the use of CeBM as a safe settlement asset. More specifically, the project will develop a proof of concept (PoC) that aims to prove the feasibility of the following functionality:

1. Retail payments are initiated by the end users via their PSP, processed and cleared by domestic interlinked IPS.

2. Currency trading and conversions are performed using a transnational network with an automated FX conversion layer and CeBM settlement.

3. The two systems are integrated in an efficient and secure manner.

Sketch of experimental architecture – Figure 1



2.2. Experiment scope and landscape

While previous BIS Innovation Hub projects have initiated the technical investigation on these topics, more work is needed to improve FX trading and settlement as a cornerstone of cross-border payments and address several remaining shortcomings. Examples are the need to maintain a pre-funded pool of different currencies at correspondent banks in multiple countries, and the limits to the scalability and reachability of decentralised solutions as well as their interoperability with existing market infrastructures.

The development of the modular FX component will consider reusability aspects, meaning that the component should allow integration with multiple payment infrastructures (including alternatives to IPS, as explained in Section 4). In this context, the project can provide insights on how transaction automation can expand the set of possible contracting outcomes and ultimately improve the efficiency of financial market infrastructures (Auer et al (2023); BIS (2023)). A crucial aspect will be addressing the economic viability of the candidate FX conversion mechanisms, potentially in collaboration with relevant stakeholders in the private and public sector. In this regard, the project will provide insights on whether automated FX conversion mechanisms can be viable in the current market and how they can be practicable to FX market operators and PSPs.

Additionally, Project Rialto combines an existing market infrastructure (IPS) with settlement in a programmable platform. Such an integration raises some specific challenges and design aspects, which will be addressed in the development phase and form an integral part of the project's contributions to improving cross-border payments (Box B).

Existing experiments in this field have focused on domestic payments interoperability. Most prominently, the Eurosystem's exploratory work on new technologies for wholesale central bank money settlement explores three interoperability-type solutions to facilitate the interaction between TARGET Services and distributed ledger technology (DLT) platforms.[1] In addition, World Bank (2024) illustrated how CBDC systems can interoperate with existing retail payment systems through an interlinking bridge that was used to route messages and API calls among different systems. The programmability features of DLT were used to link the settlement in CBDC to the transfer of funds in the IPS.

1. *For more information, see: www.ecb.europa.eu/paym/integration/distributed/exploratory/html/index.en.html*

Connecting a legacy payment system to a tokenised platform – Box B

In legacy payment systems, assets are normally represented in a digital but non-tokenised form. In Project Rialto, such systems are combined with a transnational network, where assets are tokenised (Figure B). As a result, a cross-border payment will involve converting assets from non-tokenised into tokenised form, and back.

For example, a payment may start in one IPS, then be converted into tokens in a transnational network, where FX conversion and settlement take place, and finally converted back again to non-tokenised form in the destination IPS. One option for this conversion is to have on- and off-ramps connecting the domestic IPS to the transnational ledger.

Besides moving assets to/from the tokenised platform, there is a need to exchange information with the legacy system for smooth handling of the payment process. Examples of information exchange are:

- Communicating preliminary exchange rates from the tokenised platform towards the legacy payment system, so the payee can get an initial indication of the expected rate.

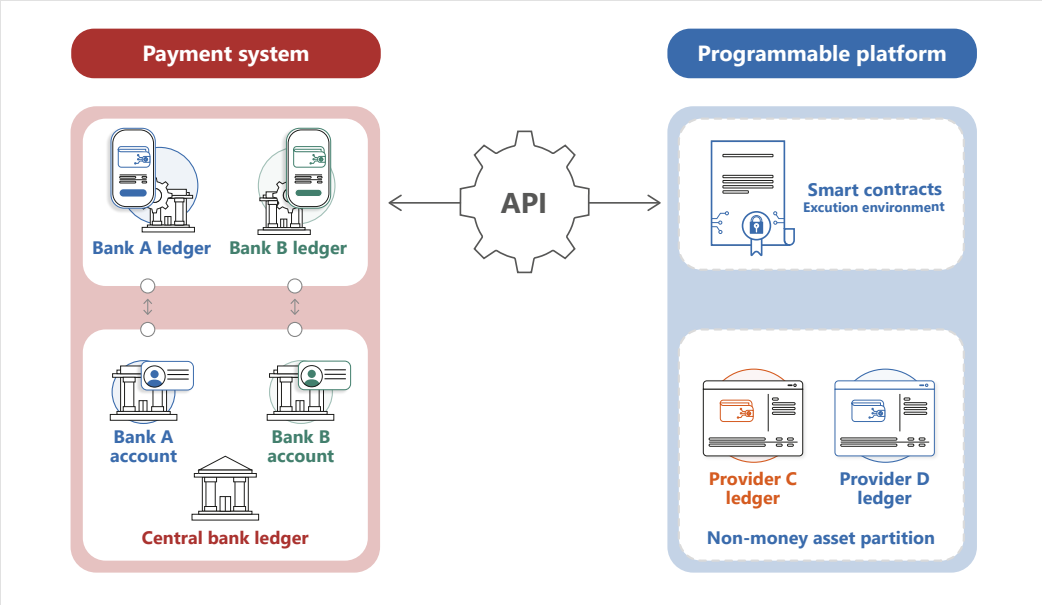
- Communicating the final exchange rate and a transaction receipt once the settlement has taken place.

- Indicating progress/status of the process from the tokenised platform to the legacy system.

- Indicating potential errors, or initiating a revert.

Current payment systems based on a flow of messages and instructions can in principle be connected to programmable platforms through standardised APIs and remote procedure call (RPC).

Standardised APIs enable interoperability between old and new systems – Figure B



Source: Adapted from BIS (2023).

3. Main use case

Project Rialto targets a global market for remittances and other person-to-person cross-border payments, which forms a significant share of some emerging market economies' GDPs. The project's focus is on instances in which the sender and receiver are located in different jurisdictions and hold their accounts at different banks and in different currencies.[2] The payment instruments used for such transactions may include bank transfers, card payments and alternative payment methods such as e-money transfers. These transactions often serve as an important income source for low-income households, supporting daily needs such as food, education and healthcare. Since 2016, global remittances have grown from around $600 billion to over $800 billon, with further growth expected in the coming years (World Bank (2023)).

Despite its importance, this market is characterised by high costs and relatively slow transaction speed. According to World Bank (2023), the global average cost of sending remittances was 6.18% of the value of transactions in the third quarter of 2023, in line with FSB (2023, 2024) estimates for $200 remittances (6.3–6.4%). Traditional banking channels are particularly expensive, with costs averaging 11.48% of the value of transactions, while digital-only money transfer operators offer lower costs.

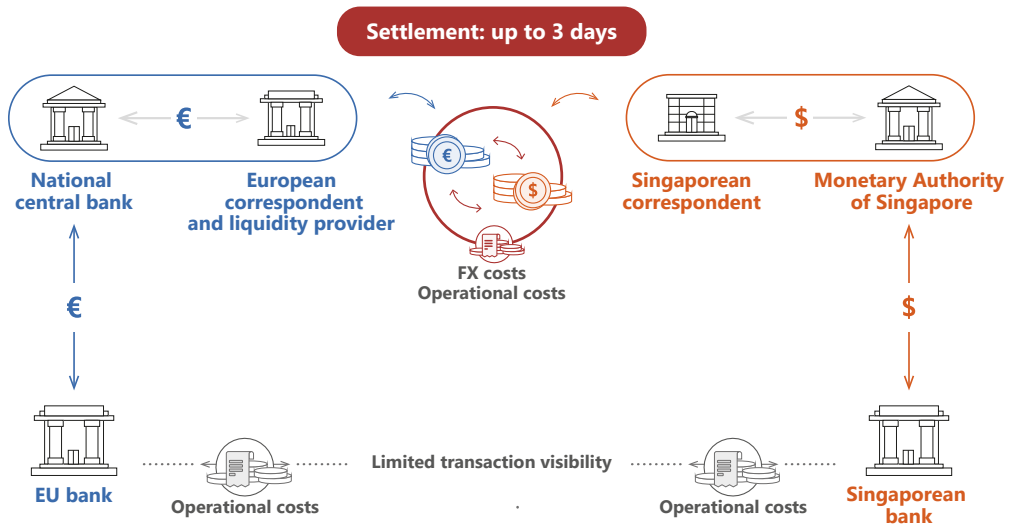
Especially low-value payments may incur high fees as a percentage of the amount sent and face cumbersome processes (FSB (2020)). This is due to several frictions. Overall, CPMI et al (2023) outline seven critical frictions for cross-border payments, namely: (I) legacy technology platforms; (II) fragmented and truncated data formats; (III) funding costs; (IV) long transaction chains; (V) weak competition; (VI) complex processing of compliance checks; and (VII) limited operating hours.

Frictions (III) and (IV) relate to the currency conversion process, which can delay payments and make them more expensive and less transparent (Figure 2). In particular, FX costs have been identified as a primary driver of total costs in retail cross-border payments (FSB (2023)).

There are considerable differences depending on the constellation of sending and receiving countries, or so-called country corridors. For example, remittances within country corridors where the receiving countries are in sub-Saharan Africa are on average significantly more expensive compared with corridors where the receiving countries are in South and East Asia (FSB (2023)). The international community has proposed several initiatives to bring the cost down, including the United Nations Sustainable Development Goals, which propose a reduction in the transaction costs of migrant remittances to less than 3% of the value of transactions by 2030, and the G20's commitment to reducing the global average cost of remittances to 5% or less.

2. The project's use case includes both remittances and other person-to-person payments. This differs from the classification in FSB (2021), which separates the two segments for monitoring purposes also to reflect the importance that the G20 has placed over a number of years in improving cost and access in the remittance market. Although the term "remittances" is sometimes applied to both corporate/business and personal payments, for the purposes of this report it is used to refer to person-to-person transfers without an underlying economic transaction, as in CPMI (2018).

Cross-border payments in the traditional interbank market – Figure 2



As regards the FX conversion process inherent to cross-currency payments, this report refers to three key phases, as defined by Börestam et al (2021):

1. **Currency trading** relates to the determination of the exchange rate for a given cross currency payment prior to its settlement.

2. **Currency conversion** relates to the way a previously identified currency conversion rate is used during the clearing and settlement processes.

3. **Settlement** concerns the movement of funds between financial institutions in relation to a cross-currency payment and the discharging of payment obligations.

Currency trading takes place in mature wholesale financial markets that have evolved in terms of technology over the past decades. For example, the increasing development of high-frequency trading has contributed to market depth and supported the creation of many new market participants (Chaboud et al (2023); Evans and Rime (2019)). However, the process through which wholesale currency trading activity underpins the currency conversion and settlement processes in retail payments is currently inefficient, lacks transparency from a pricing perspective and is responsible for some of the frictions observed in today's cross-border payments market, as outlined in the G20 roadmap (FSB (2020)).

Although existing PvP arrangements such as continuous linked settlement (CLS) have made significant progress in reducing settlement risk (see also Section 5.2), they are not available to all segments of the FX market such as emerging market and developing economy currencies in which trading has increased in recent years. In parallel, as the cross-border payments market strives to move towards real-time settlement, there has been a focus in the market for same-day or even instant PvP services that allow for fast and reliable access to liquidity in foreign currency (CPMI (2023)).

4. Financial market infrastructures

Project Rialto will focus on interlinked IPS as a main use case, but the FX component developed in the Project will consider reusability aspects. This means that it should allow for integration with the other types of financial market infrastructures.

In what follows, we describe three key scenarios envisioned in terms of future payment infrastructures for instant retail cross-currency payments, namely: interlinked IPS, multi currency clearing and settlement mechanisms (CSM) and programmable digital asset systems.

To settle cross-currency payments, all three types of infrastructures would need an FX component, which could be delivered by third parties or automated mechanisms, as explained in Section 6. Furthermore, such cross-border infrastructures should include mechanisms to adequately manage the risks and complexities associated with FX transactions, time zone differences and the legal and regulatory frameworks of the different jurisdictions involved, all of which tend to be major barriers in setting up cross-border payment systems (Bech et al (2020)).

4.1. Interlinked instant payment systems

In the future, domestic IPS may become increasingly interlinked across borders as multilateral platforms meet a growing demand for new and improved cross-border payment services. This is driven by deeper economic and financial integration at both global and regional levels (CPMI et al (2023)).

Interlinked IPS require connecting two (or more) domestic IPS,[3] enabling real-time secure and efficient transfers of funds across jurisdictions. The interlinking can be bilateral, where each domestic IPS establishes a bespoke connectivity with a reciprocating IPS, or multilateral, through an adapter or hub/gateway (as in Project Nexus (BISIH (2023a))). The interlinking mechanism provides the transposition of payment messages to harmonise the different domestic payment message standards, the routing of payment messages and responses to and from the destination domestic IPS, alleviating the need to establish bespoke connectivity between IPS, and potentially allowing for centralised screening and analysis of payment instructions for anti-money laundering/countering the financing of terrorism (AML/CFT) requirements.

3. Or regional IPS, in the case of IPS that serve an entire region. One example is TIPS in Europe.

4.2. Multi-currency clearing and settlement mechanisms

A multi-currency CSM is an IPS that has settlement capabilities in several currencies. Similar infrastructures without instant settlement capabilities already operate in the cross-border payments market (see Bech et al (2020) for a review).

Within a multi-currency CSM for instant payments, accounts in multiple currencies can coexist and PSPs can interact directly with the CSM to send and receive instant payments in different currencies. An example of such infrastructure is TIPS, the Eurosystem IPS. While cross-currency capabilities will be explored in future experiments,[4] Börestam et al (2021) describe conceptually how TIPS could allow for the clearing and settlement of instant transactions using multiple currencies.

4.3. Programmable digital asset systems

The tokenisation of settlement assets such as CoBM and CeBM opens the possibility of simplifying complex processes. A payment infrastructure based on programmable assets and liabilities could be used to represent the value being transferred and traded between parties in different countries. This could simplify processes and payment flows and remove the reliance on additional intermediaries.

A programmable payment infrastructure also offers the potential to deliver rapid transactions across borders through a real-time ledger. Operationally, it offers increased accessibility and the automation of payment processes, making human error less likely. However, the success of a completely tokenised environment will require broad adoption of specific technologies such as DLT, the capacity to process a large amount of transactions (scalability) and the management of cyber security and operational resilience.

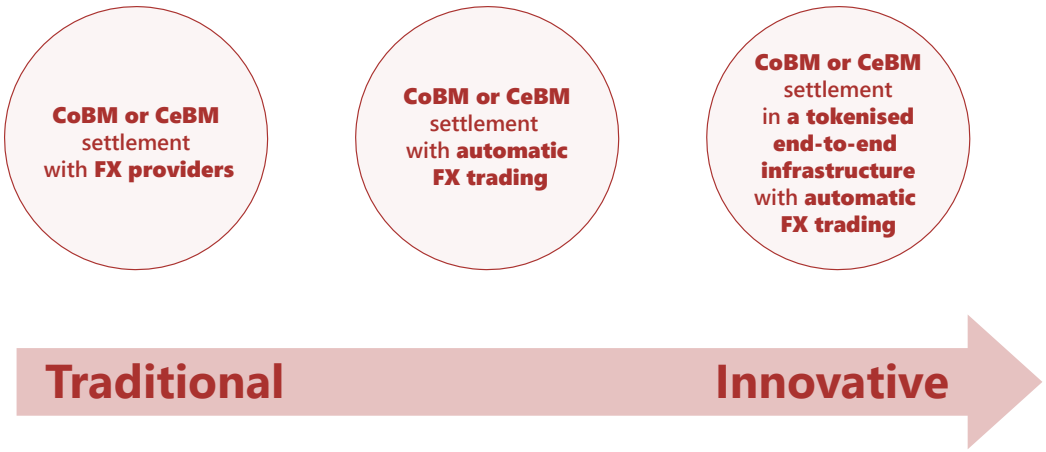
4. The Governing Council of the ECB has recently decided to continue the work on cross-currency settlement in TIPS as well as additional initiatives aimed at linking TIPS with other fast payment systems globally, including potentially the multilateral network developed as part of Project Nexus by the BIS (www.ecb.europa.eu/home/doc/ecb.doc241021_TIPS_to_connect_to_other_fast_payment_systems.en.pdf).

5. Settlement assets

Project Rialto will focus on experimenting with the role of CeBM as a settlement asset. Hence, it is important to clearly define it in relation to what other options are available today or could become available in the future, also in relation to the currency trading and conversion processes.

This section reviews the main types of settlement assets for cross-border payments, namely CoBM, CeBM and their tokenised counterparts. The next section describes how FX services could be provided by third-party intermediaries (eg correspondent banks or FX providers) or automatically (such as a hub for FX services or smart contracts in a programmable platform). These alternatives can be combined and mapped from more traditional to more innovative, as represented in Figure 3.

Settlement options for cross-currency payments – Figure 3

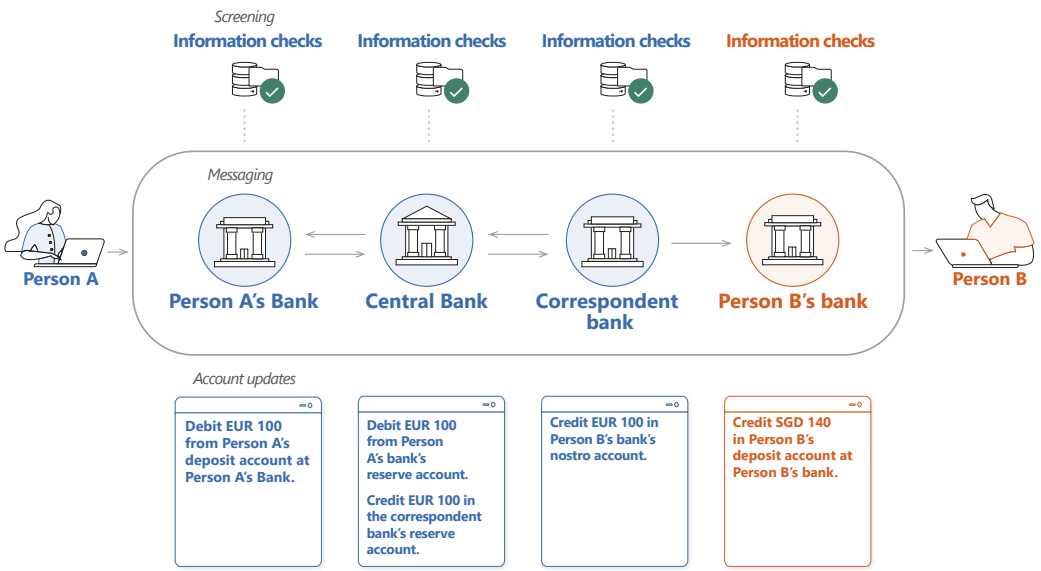


5.1. Role of commercial bank money

CoBM is the most commonly used instrument in today's cross-border payments market to settle international transactions. Usually, cross-currency payments are settled through intermediary bank accounts (called nostro or vostro accounts) held at correspondent banks, and imply a long chain of back-end operations (Figure 4).

The reliance on such correspondent banking networks and the complex payment chain can explain why cross-border payments can be costly, lack transparency and take a long time to settle due to various timetables and jurisdictions' different rules and constraints.

Settlement of a cross-border transaction using correspondent banking – Figure 4



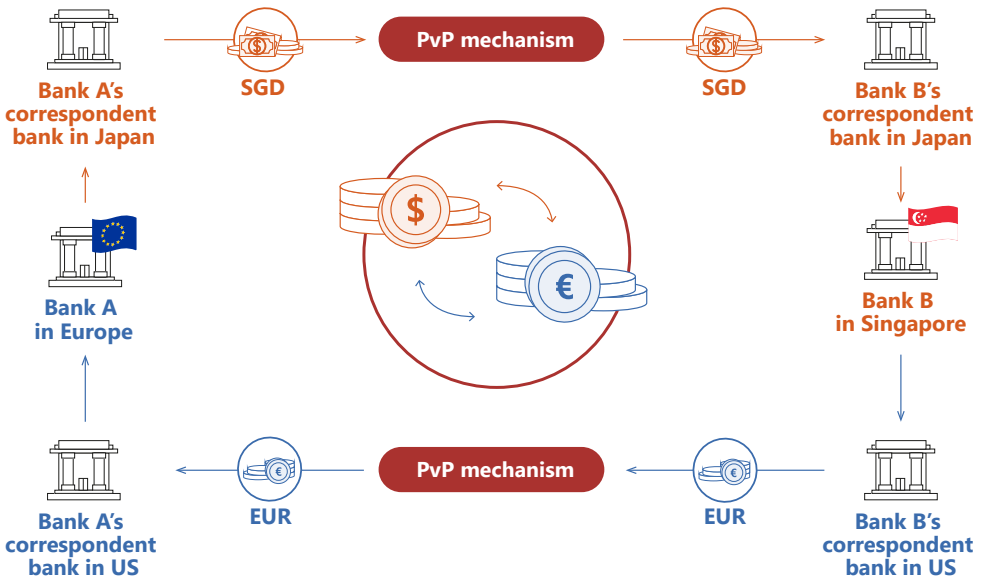
Source: Adapted from Garratt et al (2024).

5.2. Role of central bank money

An alternative to correspondent bank intermediation and CoBM as a settlement medium is commercial banks being able to use their reserves at the central bank to settle international transactions. Within the back-end process, one way to settle a cross-border payment is to connect CoBM with CeBM by introducing a PvP mechanism. One prominent example is CLS, which operates in the wholesale payments segment.

PvP is a settlement mechanism that ensures that the final transfer of a payment in one currency occurs if and only if the final transfer of a payment in another currency or currencies takes place (CPMI (2022a, 2023)). Correspondent banks still have a role in this scenario, acting in different jurisdictions to trade different currency pairs and maintain the required liquidity for each currency involved in the transaction. Figure 5 summarises this.

Settlement of a cross-border transaction on a payment-versus-payment (PvP) basis – Figure 5



5.3. Tokenised CoBM and CeBM

The large number of processing steps in cross-border payments could potentially be streamlined and simplified through tokenisation and the use of a common programmable platform (BIS (2023)). Tokenisation is the process of recording claims on real or financial assets that exist on a traditional ledger onto a programmable platform (Aldasoro et al 2023).

From a market infrastructure and settlement perspective, the introduction of a common programmable platform and a tokenised form of public money (wCBDC being one example; see Box C) is one method to overcome the risk of fragmentation in the digital financial marketplace (see also BIS and CPMI (2024)). This would avoid the coexistence of different protocols, messaging standards and smart contracts in different platforms, or a fragmentation of settlement instruments. The latter refers to a situation in which tokenised CoBM and CeBM coexist with other forms of private tokenised money, such as stablecoins, which entails a number of risks related to potential departures from singleness (Garratt and Shin (2023)).

Wholesale CBDC – Box C

Wholesale CBDC (wCBDC) refers to central bank money available in digital form exclusively for wholesale transactions between banks. It therefore enables the settlement of interbank transfers and related wholesale transactions in central bank reserves. As explained in Panetta (2022), some can misinterpret wCBDC to mean large-value payments in central bank money, irrespective of the parties involved in the transaction.

The discussion surrounding wCBDC tends to be split into two arguments. One claims that wCBDC has existed for decades as a digital means for the settlement of transactions between banks in central bank money. Another claims that wCBDC is something new, made possible by the emergence of DLT and the use of tokenisation and has different functionalities than current central bank reserves.

Proponents of the latter argument highlight a range of benefits derived from DLT compared with current infrastructures and central bank reserves, such as the possibility of settling transactions instantly, around the clock, in a wider range of assets and with a broader spectrum of participants, potentially including non-financial corporations. However, these benefits can also be obtained in other ways, including by enhancing existing systems.

One proposed benefit of settlement in wCBDC via DLT is to use smart contract capabilities to allow for new forms of programmability, for example by requiring that a payment only settles on condition of delivery of another payment (PvP) or delivery of an asset, ie delivery versus payment (DvP). This could encompass a broad variety of conditional payment instructions, going far beyond today's DvP mechanism in real-time gross settlement (RTGS) systems (BIS (2021)).

A key difference between the two arguments relates to the provision of CeBM into a broader set of infrastructures, including infrastructures not owned or operated by the central bank. In conventional payment systems, central banks directly operate an infrastructure and provide CeBM in dedicated accounts that are opened for a limited number of participants who are subject to regulatory requirements. As the owner and operator of the system, only the central bank exercises control over its settlement asset. On the other hand, in distributed systems there is not necessarily a single operator and wCBDC can be distributed via an external DLT operated by a third party, rather than the central bank (Bank of France (2023)). As an example, Project Mariana (BISIH (2023c) explored how wCBDC issued on domestic DLTs can be bridged to a transnational DLT operated by a decentralised set of validators. In this regard, wCBDC can be considered something new that has additional functionalities compared with current central bank reserves.

In particular, the role of CBDC at a wholesale level, ie interbank transactions, could facilitate settlement operations. In the future financial system, PSP or commercial banks could acquire wCBDC by depositing money with the central bank or its designated operator, and request for it to be converted into wCBDC. The wCBDC could then be transacted on a platform provided by the central bank or an authorised third party to PSP and commercial banks and then redeemed through the central bank or its designated operator.

6. FX market-making approaches

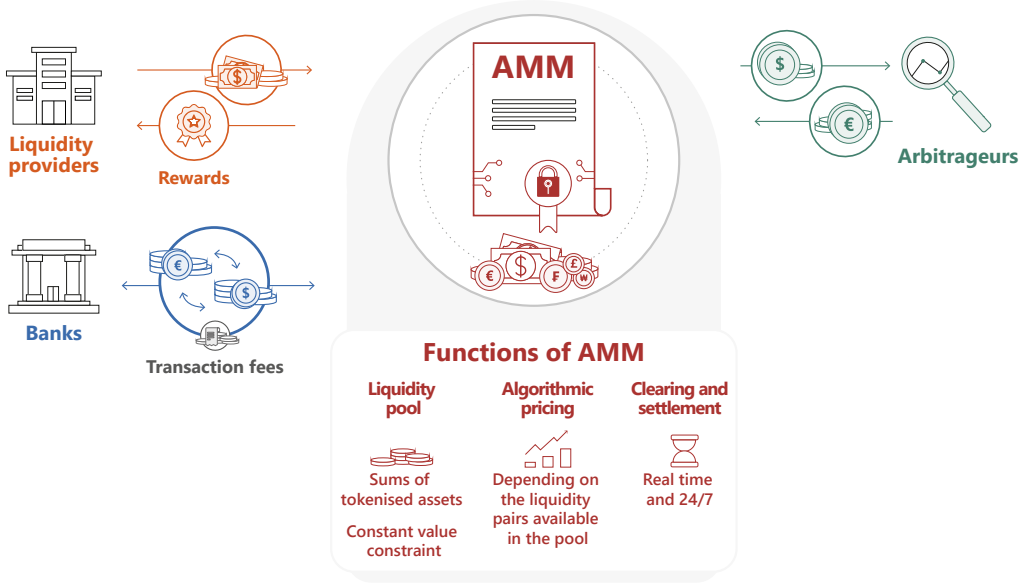
Project Rialto will explore a new automated FX settlement solution based on innovative approaches developed in the decentralised finance (DeFi) ecosystem. This section takes a closer look at these approaches in relation to the current arrangements, while the next section reviews how FX services have been modelled in previous PoCs.

For the processing of a cross-currency transaction, FX services are essential for both clearing and settlement operations. Among the market-making options currently available, the most important are third-party providers (eg banks, FX dealers and commercial companies). Among the innovative solutions are a number of decentralised exchanges that are already used in the cryptoasset market, such as automated market makers (AMMs), decentralised order books and hybrid solutions. Table 1 summarises and compares their main features.

6.1. Automated market makers

The AMM concept comes from the DeFi ecosystem as an alternative to centralised exchanges. An AMM is an exchange mechanism used in decentralised markets. It takes the form of a liquidity pool which is the sole counterparty to foreign exchange transactions. In practical terms, the liquidity pool consists of one or more smart contracts that hold liquidity (eg wCBDCs from each jurisdiction) and enable participants to deposit and withdraw tokenised currencies or cryptoassets at a price predetermined by a bonding curve according to a specific pricing formula (Figure 6).

Functioning of an AMM – Figure 6



6.2. Decentralised order books

A decentralised order book is a trading mechanism where buy and sell orders are matched through a distributed network of nodes – ie in a decentralised exchange (DEX) – rather than being centralised in a single location or controlled by a single entity. In a decentralised order book, users can submit orders and execute trades without the need for intermediaries or central authorities, which helps users achieve the prices they want more closely and improves transparency. These exchanges can be both on-chain, if transactions are recorded and executed on the blockchain, or off-chain, if only the settlement of the final trades happens on the blockchain and trade-related information such as asset positions and prices occurs off-chain. Intent-based architectures are an emerging phenomenon where the user just signs an intent (eg, swap x amount of currency A for at least y amount of currency B), leaving the execution of the transactions in between to sophisticated third parties.

6.3. Hybrid DEX and aggregators

It has been argued that both AMMs and order books have price efficiency challenges when it comes to sourcing liquidity. These inefficiencies have been tackled by hybrid solutions. Specifically, one can use decentralised exchanges that have some elements of both AMMs and order books. As an example, in a hybrid DEX the order for a specific currency could first be sent to the order book, looking for sell orders of the same value. In case the liquidity for the required currency pair is thin on the order book, the order would be routed to the AMM to find a more efficient liquidity source.

Comparison of FX market-making mechanisms – Table 1

	Third-Party FX Providers	Automated Market Makers	Orderbooks DEX	Hybrid DEX and aggregators
FX rates	Not fully transparent and competitive across jurisdictions	Competitive, based on liquidity pool and pricing formula	Competitive, depending on market depth	Competitive, thanks to access to multiple exchanges
Transaction costs	High to moderate, depending on the service provider and payment destination	Low, depending on choice of network and gas fees	Low, depending on choice of network and gas fees	Low, depending on choice of network and gas fees
Order latency	Slow to moderate, depending on the service provider and payment destination	Fast, thanks to automated swap mechanisms	Moderate, depending on market depth	Fast, thanks to automated swap mechanisms
Liquidity	Unbalanced, depending on the market served and network size	Balanced, depending on the composition of the liquidity pool	Moderate, depending on market depth	High, thanks to access to multiple funding sources

7. FX services in technological experiments

To provide the background against which Project Rialto will be developed and to set out its expected contribution, this section reviews how recent technological experiments have modelled FX services in the context of cross-border payments (both retail and wholesale).

While in the few existing multi-currency systems FX conversion services are provided by central banks,[5] in most technological experiments FX services are assumed to be provided by financial intermediaries including commercial banks or other PSPs, while other projects have explored the role of automated on-chain solutions. This section reviews the existing approaches used to model FX services in the context of experimental work and PoCs conducted in the public and private sectors.

Table 2 summarises the main characteristics of BIS Innovation Hub projects on cross-border payments in terms of infrastructure and FX trading and settlement features and provides a comparison with Project Rialto (which is outlined in the next section). Other projects developed by the central banking community outside the Innovation Hub network and in the private sector are also reviewed below.

Cross-border payments projects at the BIS Innovation Hub – Table 2

Name	Wholesale/ retail	CeBM settlement	FX services	Infrastructure	PvP	DvP
Nexus	Retail	✗	3P provider	Legacy	✗	✗
ILR2/mBridge	Wholesale	✓	Bilateral	Next gen	✓	✗
Jura	Wholesale	✓	3P provider	Next gen	✓	✓
Dunbar	Wholesale	✓	3P provider	Next gen	✓	✗
Mariana	Wholesale	✓	Automated	Next gen	✓	✗
Icebreaker	Retail	✗	3P provider	Next gen	✓	✗
Meridian FX	Wholesale	✓	N/A	Next gen	✓	✗
Agorá	Wholesale	✓	N/A	Next gen	✓	✓
Rialto	Retail	✓	Automated	Legacy + next gen	✓	✗

Source: BIS Innovation Hub.

5. *Examples are Directo a México, or the Gulf Cooperative Council RTGS system; see Bech et al (2020).*

A comprehensive review of the experiments related to cross-border CBDC conducted at the BIS Innovation Hub (Bech et al (2023) covers four projects: InthanonLionRock2, Jura, Dunbar and mBridge. The review reveals that platforms with two or more CBDCs are technically feasible and could lower costs, make settlement faster and increase operational transparency. All four projects dealt with cross-currency exchanges on a DLT platform and for three projects FX trading was performed off-platform and their details were used for settling transactions on a blockchain. However, in InthanonLionRock2 FX trading could also be performed on-platform ("posted board rate" and "request for quote"). These services are provided by the participating entities who either request that their counterparts provide quotes or can view directly on the board the rates posted by their counterparts.

Project Icebreaker (BISIH (2023b)) assumed that FX providers are intermediaries that have a formal agreement with the cross-border arrangement to offer FX quotes to everyone in the hypothetical hub system and to provide liquidity for the currencies of the three jurisdictions involved in the experiment. The FX providers are assumed to have CBDC wallets in multiple systems for simplicity. The project also addressed the case where direct quotes for a currency pair may be either unavailable or uncompetitive through the use of a third currency in the hypothetical hub system as a bridge to fulfil the FX need.

In Project Nexus (BISIH (2023a)), FX services are assumed to be provided by FX providers that are in competition with each other to provide the best rates for each currency pair. To make a cross-currency payment possible, FX providers receive the source currency from the payer's PSP and deliver the destination currency to the beneficiary's PSP. This enables the payer's PSP to make a payment to the beneficiary's PSP, even though the payer's PSP never directly holds the destination currency. A critical point in Nexus is that a cross-currency payment requires an actor which is willing and able to exchange one currency for another. These would be regulated financial institutions that are willing to accept the source currency from the sender and pay out the destination currency to the recipient.

In Project Mariana (BISIH (2023c)), wCBDC tokens issued by the central bank are exchanged by commercial banks via a transnational platform by means of interaction with an AMM. In the prototype, exchange rates are automatically set by the AMM smart contract depending on the composition of the liquidity pool and a pricing formula. Therefore, there is no need for an external FX service provider to offer quotes and rates to exchange the wCBDC tokens. In this sense, the FX service provider is the AMM itself. This framework requires participating banks to maintain a pool of wCBDC so that liquidity can be tapped by the AMM smart contract for the purpose of settling cross-border interbank transactions.

Table 2 includes projects that have recently been launched and are expected to deliver results in 2025. Project Meridian FX will build upon the concept of a "synchronisation operator" from Project Meridian, enabling it to connect RTGS systems in two different jurisdictions (the UK and EU) and orchestrating instant settlement of a PvP FX transaction. Project Agorá explores the concept of a unified ledger across seven jurisdictions, combining tokenised versions of CeBM, CoBM, and digital assets on the same programmable platform. In both experiments, FX services are not explicitly modelled.

Other experiments within the central banking community include a PoC where cross-currency FX services are assumed to be provided by a specialised intermediary (a simulated cross-currency PSP) (Renzetti et al (2022)). More specifically, the cross-currency specific information was inserted in the payment instruction message (a pacs.008 message) to convey the information related to the exchange rate, the amount converted into the destination currency and what the destination currency is.

Regarding the experiments conducted in the private sector, Swift (2022) explores how new market infrastructures can effectively collapse the steps of trade and settlement into a single step. It builds a simple FX solution from a conceptual point of view based on an international FX marketplace in which the trading and settlement of spot FX transactions between commercial banks happen via smart contracts using CBDCs. It also explores the potential of a CLS-like settlement engine to mitigate the settlement risk for cross-CBDC FX settlement, with similar protection as for fiat currency. FX services and market-making were assumed to be bilaterally agreed among the parties in the international FX network, although the possibility to integrate the infrastructure with automated market makers is mentioned as a possible next step.

Additionally, other private sector initiatives aimed at improving cross-border payments include Visa B2B Connect as a solution for businesses worldwide that features the option of using participants' own or Visa's FX rates for foreign currency payments (Visa (2023)) together with Swift Payment Pre-validation.[6]

Finally, recent research on on-chain FX services developed in the private sector in the context of cross-border payments has argued that on-chain solutions can have beneficial effects on the remittances market and for smaller enterprises seeking FX services at low cost (Adams et al (2023)). Such benefits are directly related to enhanced liquidity, transparency and market integrity, and reduced settlement risk as well as a good level of price efficiency, in line with the findings of the academic literature on this topic (Barbon and Ranaldo (2024); Malinova and Park (2023)). However, there are still gaps in the viability of on-chain FX solutions in current payment systems that relate to aspects such as their scalability, the dependency on fiat on-ramps for the digital representation of fiat currency, and the evolving regulatory framework in many jurisdictions (Adams et al (2023)).

6. That is, a method to enable upfront checks of Visa B2B Connect payments, reducing unnecessary delays by catching potential errors before the payment is initiated (Swift (2023)).

8. Remaining challenges

There are additional considerations and challenges that must be accounted for when assessing the feasibility of implementing retail cross-border payments with the approach proposed in Project Rialto.

First, **governance and legal** aspects need to be taken into account. For cross-border transactions, there must be clarity as to which country's laws and courts have jurisdiction over the transaction, as well as governance rules for the interlinking and FX mechanisms. Each market participant in the cross-border transaction should have an understanding of the applicable laws and how these affect the enforceability of rights and obligations with other market participants, while aiming to minimise material legal risks. Market participants must also have an awareness of, and ensure compliance with, tax codes, AML regulations and know-your-customer (KYC) requirements and sanctions lists. Some countries have currency controls that restrict the flow of their national currency outside their borders – this could give rise to limitations on the amount of money that can be transferred or require special permissions for certain transactions. Therefore, market participants should have legal agreements in place with their counterparties, while using standard terms and conditions (where appropriate) to minimise misinterpretations of contractual agreements between jurisdictions.

Relatedly, **digital fraud risks** associated with instant payments, especially from a cross-border perspective, should be taken into account. These risks are significant due to the speed and global nature of cross-border transactions. Risks include identity theft, phishing scams, account takeover, money laundering, social engineering, insider threats, transaction manipulation, fraudulent currency conversion services and exploitation of gaps between different regulatory frameworks (regulatory arbitrage). Good measures to prevent such risks should be taken into account by policymakers in the context of the ongoing efforts to improve cross-border payments, which tend to be riskier for consumers than domestic payments, as shown in recent research (Cologgi (2023)).

Exchange rate volatility can cause price instability and erode confidence in the transnational network as a stable and reliable settlement layer, especially if the network is supposed to maintain a peg to the FX market. Additionally, price differences might develop during the processing of the transactions that could give rise to market exposure for consumers and liquidity providers. An automated FX conversion layer would need to manage this risk, potentially through hedging strategies or rapid settlement protocols. Furthermore, certain countries have strict regulations on who can exchange currencies and under what circumstances. These restrictions can prevent or delay automated conversions, especially if they require manual intervention or approval from authorities. An automated FX conversion layer would need to navigate these complexities, which could introduce legal and operational challenges.

Efficient **price discovery** and **liquidity use mechanisms** are essential for the transnational network to reflect the true value of the underlying currencies. This refers to the process of determining the price of currencies in the automated FX marketplace through the interactions of buyers and sellers and based on efficient liquidity management. Inadequate price discovery mechanisms can leave currencies vulnerable to manipulation, where certain actors could influence the price to their advantage, potentially harming other users. The number and diversity of participants in the automated FX market can have an influence on this process, since a market dominated by a few players may lead to less competitive pricing, while a broad base of participants can enhance competition and price efficiency.

9. Conclusion and next steps

More than $800 billion worth of transactions take place every year in the retail cross-border payments market. Despite their growing size and importance, retail cross-border transactions lag domestic ones in terms of cost, speed, access and transparency because of the complex processes they involve.

Project Rialto seeks to address the FX- and settlement-related challenges in retail cross-border payments by combining interlinked IPS with an automated FX conversion solution and settlement in tokenised central bank money. In outlining the main features and challenges in the retail cross-border payments market, with a focus on financial market infrastructures, foreign exchange, tokenised money and settlement procedures, this report has identified the main policy and technical aspects to be considered in Project Rialto.

In the next steps, the project will develop a PoC to prove the technical feasibility of retail cross-border payments using interlinked IPS together with an automated FX wholesale conversion layer that allows the use of tokenised central bank money as a safe settlement asset. Details of the PoC, as well as lessons learned from the experiment, will be described in the final project report.

Project participants and acknowledgments

BIS Innovation Hub Eurosystem Center

Raphael Auer (Centre Head)
Massimiliano Cologgi (Adviser)
Christelle Therville (Administrative Officer)
Andras Valko (Deputy Centre Head)

BIS Innovation Hub Singapore Centre

Balu Babu (Intern)
Sonja Davidovic (Adviser)
Maha El Dimachki (Centre Head)
Friedrich Klinger (Adviser)

Bank of Italy

Paolo Bramini (Director, Payment Systems Directorate)

Bank Negara Malaysia

Qaiser Iskandar Anwarudin (Director, Payment Services Policy Department)
Norasyikin Mohamad Razali (Deputy Director, Payment Services Policy Department)
Doulos Paul Lee (Manager, Payments Services Policy Department)
Ong Shu Ting (Analyst, Payments Services Policy Department)
Alyssa Tan Yuen Yee (Associate Analyst, Payments Services Policy Department)

Bank of France

Nicolas Barbaroux (Economist, Innovation and financial market infrastructures)
Cédric Coiquaud (Business Analyst, Information Systems for Markets and European Infrastructures)
Clément Delaneau (Blockchain Engineer, Blockchain Division)
Claudine Hurman (Director, Innovation and financial market infrastructures)
Khai Uy Pham (Adviser, Innovation and financial market infrastructures)
Louis-Amaury Pelissier (Blockchain Engineer, Blockchain Division)
Salim Talout Zitan (Blockchain Engineer, Blockchain Division)
Thomas Zoughebi (Business Analyst, Innovation and financial market infrastructures)

Monetary Authority of Singapore

Alan Lim (Director and Head, Financial Technology and Innovation Group)
Lizhi Chen (Deputy Director, Financial Technology and Innovation Group)
Jaelyn Teo (Assistant Director, Financial Technology and Innovation Group) (Till Jan 2025)

Project observers

Johannes Rogowsky (Deutsche Bundesbank)
Sjoerd Van der Vaart and Miguel Bayona Perez (European Central Bank)

Acknowledgements

The authors are grateful to Jon Frost, Stephanie Haffner, Francesca Hopwood, Anneke Kosse, Cristina Picillo, Björn Segendorff, Cecilia Skingsley and William Zhang for reviewing this report and providing extremely valuable feedback. The authors also wish to thank Rudolf Biczok, Ben Dyson, Louise Egan, Masami Inoue, Kah Kit Yip and Eleni Siskou.

References

Adams, A, M Lader, G Liao, D Puth and X Wan (2023): "On-chain foreign exchange and cross-border payments", mimeo, papers.ssrn.com/sol3/papers.cfm?abstract_id=4328948.

Aldasoro, I, S Doerr, L Gambacorta, R Garratt and P Koo Wilkens (2023): "The tokenisation continuum", BIS Bulletin, no 72, www.bis.org/publ/bisbull72.htm.

Auer, R, P Haene and H Holden (2021): "Multi-CBDC arrangements and the future of cross-border payments", BIS Working Papers, no 115, www.bis.org/publ/bppdf/bispap115.htm.

Auer, R, B Haslhofer, S Kitzler, P Saggese and F Victor (2023): "The technology of decentralised finance (DeFi)", BIS Working Papers, no 1066, www.bis.org/publ/work1066.htm.

Aurazo, J, H Banka, J Frost, A Kosse and T Piveteau (2024):"Central bank digital currencies and fast payment systems: rivals or partners", BIS Papers, no 151, www.bis.org/publ/bppdf/bispap151.htm.

Bank of France (2023): "Wholesale central bank digital currency experiments with the Banque de France", www.banque-france.fr/system/files/2023-08/Banque_de_France_stabilite_financiere_rapport_mnbc_2023.pdf.

Barbon, A and A Ranaldo (2024): "On the quality of cryptocurrency markets: centralized versus decentralized exchanges", papers.ssrn.com/sol3/papers.cfm?abstract_id=3984897.

Bech, M, U Faruqui and T Shirakami (2020): "Payments without borders", BIS Quarterly Review, March, www.bis.org/publ/qtrpdf/r_qt2003h.pdf.

Bech, M, C Boar, D Eidan, P Haene, H Holden and W K Toh (2023): "Using CBDCs across borders: lessons from practical experiments", Journal of Payments Strategy & Systems, vol 17, no 1, pp 46–57, www.bis.org/publ/othp51.htm.

Bindseil, U and G Pantelopoulos (2022): "Towards the holy grail of cross-border payments",ECB Working Paper Series, www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2693~8d4e580438.en.pdf.

BIS (2021):"CBDCs: an opportunity for the monetary system",Annual Economic Report 2021, Chapter III, www.bis.org/publ/arpdf/ar2021e3.htm.

BIS (2022):"Triennial Central Bank Survey of Foreign Exchange and Over-the-counter (OTC) Derivatives Markets in 2022", www.bis.org/statistics/rpfx22.htm.

——— (2023): "Blueprint for the future monetary system: improving the old, enabling the new", Annual Economic Report 2023, Chapter III, www.bis.org/publ/arpdf/ar2023e.htm.

BIS and CPMI (2024): "Tokenisation in the context of money and other assets: concepts and implications for central banks. Report to the G20", Bank for International Settlements, https://www.bis.org/cpmi/publ/d225.pdf.

BIS Innovation Hub (BISIH) (2023a): "Project Nexus: enabling instant cross-border payments", www.bis.org/about/bisih/topics/fmis/nexus.htm.

——— (2023b): "Project Icebreaker: breaking new paths in cross-border retail CBDC payments", www.bis.org/publ/othp61.pdf.

——— (2023c): "Project Mariana: cross-border exchange of wholesale CBDCs using automated market makers", www.bis.org/publ/othp75.htm.

——— (2024): "Project Rialto: improving instant cross-border payments using central bank money settlement", www.bis.org/about/bisih/topics/cbdc/rialto.htm.

Boar, C, S Claessens, A Kosse, R Leckow and T Rice (2021): "Interoperability between payment systems across borders", BIS Bulletin, no 49, www.bis.org/publ/bisbull49.htm.

Börestam, A, F Dinacci and M Renzetti (2021): "Cross-currency settlement of instant payments in a multi-currency clearing and settlement mechanism", www.bis.org/events/cpmi_ptfop/proceedings/paper8.pdf.

Chaboud, A, D Rime and V Sushko (2023): "The foreign exchange market", in R Gürkaynak and J Wright (eds), The research handbook of financial markets, Edward Elgar, ssrn.com/abstract=4063213.

Cologgi, M (2023): "The impact of regulation on retail payments security: evidence from Italian supervisory data", Finance Research Letters, vol 54, 103799, www.sciencedirect.com/science/article/abs/pii/S1544612323001721.

Committee on Payments and Market Infrastructures (CPMI) (2018):"Cross-border retail payments", www.bis.org/cpmi/publ/d173.pdf.

——— (2022a): "Facilitating increased adoption of payment versus payment (PvP)", www.bis.org/cpmi/publ/d207.pdf.

——— (2022b): "Interlinking payment systems and the role of application programming interfaces: a framework for cross-border payments", www.bis.org/cpmi/publ/d205.htm.

——— (2023): "Facilitating increased adoption of payment versus payment (PvP)", www.bis.org/cpmi/publ/d216.pdf.

CPMI, BIS Innovation Hub, IMF and World Bank (2023): "Exploring multilateral platforms for cross-border payments", www.bis.org/cpmi/publ/d213.pdf.

Evans, M and D Rime (2019): "Microstructure of foreign exchange markets", https://ssrn.com/abstract=3345289.

European Commission (2020a): "A Capital Markets Union for people and businesses-new action plan", eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0590.

——— (2020b): "Retail payments strategy for the EU",www.ecb.europa.eu/paym/integration/retail/retail_payments_strategy/html/index.en.html.

FSB (2020): "Enhancing Cross-Border Payments, stage 3 roadmap", www.fsb.org/2020/10/enhancing-cross-border-payments-stage-3-roadmap/.

——— (2021): "Targets for Addressing the Four Challenges of Cross-Border Payments, Final Report", www.fsb.org/uploads/P131021-2.pdf.

——— (2023): "Annual Progress Report on Meeting the Targets for Cross-border Payments: 2023 Report on Key Performance Indicators", www.fsb.org/uploads/P091023-1.pdf.

——— (2024): "Annual Progress Report on Meeting the Targets for Cross-border Payments: 2024 Report on Key Performance Indicators", www.fsb.org/uploads/P211024-3.pdf.

Garratt, R, P Koo Wilkens and H S Shin (2024): "Next-generation correspondent banking", BIS Bulletin, no 87, www.bis.org/publ/bisbull87.pdf.

Garratt R and H S Shin (2023): "Stablecoins versus tokenised deposits: implications for the singleness of money", BIS Bulletin, no 73, https://www.bis.org/publ/bisbull73.pdf.

Glowka, M and T Nilsson (2022): "FX settlement risk: an unsettled issue", BIS Quarterly Review, December, www.bis.org/publ/qtrpdf/r_qt2212i.htm.

Malinova, K and A Park (2023): "Learning from DeFi: would automated market makers improve equity trading?", papers.ssrn.com/sol3/papers.cfm?abstract_id=4531670.

Panetta, F (2022): "Demystifying wholesale central bank digital currency", speech at the Deutsche Bundesbank symposium "Payments and securities settlement in Europe – today and tomorrow", Frankfurt am Main, 26 September, www.bis.org/review/r220926b.htm.

Renzetti, M, A Dimartina, R Mancini, G Sabelli, F Stasio, C Palmers, F Alhijawi, E Kaya, C Piccarelle, S Butler, J Vasani, G Esposito, A Tiberino and M Caracausi (2022): "Cross-currency settlement of instant payments in a cross-platform context: a proof of concept",Bank of Italy Markets, Infrastructures, Payment Systems, www.bancaditalia.it/pubblicazioni/mercati-infrastrutture-e-sistemi-di-pagamento/approfondimenti/2022-019/index.html?com.dotmarketing.htmlpage.language=1.

Swift (2022): "Connecting digital islands: paving the way for global use of CBDCs and tokenised assets", www.swift.com/news-events/news/connecting-digital-islands-paving-way-global-use-cbdcs-and-tokenised-assets.

——— (2023): "Visa and Swift team up to enhance transparency, speed and security in global B2B money movement", www.swift.com/de/node/309348.

Visa (2023): "Visa B2B Connect", usa.visa.com/partner-with-us/payment-technology/visa-b2b-connect.html.

World Bank (2023): "Leveraging diaspora: finances for private capital mobilization", Migration and Development Brief 39, documents.worldbank.org/en/publication/documents-reports/documentdetail/099740408142422676/idu184dfd61b1e135142421a20213728b2e8fa86.

——— (2024): "Interoperability between central bank digital currency systems and fast payment systems: a technical perspective", Technology & Innovation Lab, hdl.handle.net/10986/41812.

Bank for International Settlements (BIS)

ISBN 978-92-9259-829-7 (Online)