NBS Nottingham Business School

Central Bank Digital Currencies (CBDCs)

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Learning Outcomes

- Central Bank Digital Currencies (CBDCs)
- CBDCs Technology and IT Architecture
- Distributed Ledger Technology (DLT) and Blockchain: Limitations and Risks Over CBDCs and Beyond
- Stablecoins vs CBDCs: Systemic Risks and Financial Stability
- **Case Study 1**. Payment System and CBDC in the UK (Digital Pound)
- **Case Study 2**. ECB's CBDC (Digital Euro): Proof-of-Concept on Corda
- **Research Activity 1. [Brainstorming:** The Cross-Border and Regional Level of CBDC's Projects]

Central Bank Digital Currencies (CBDCs)

Central Bank Digital Currency is the digital form of a country's fiat currency that is also a claim on the central bank. Instead of printing money, the central bank issues electronic coins or accounts backed by the full faith and credit of the government.

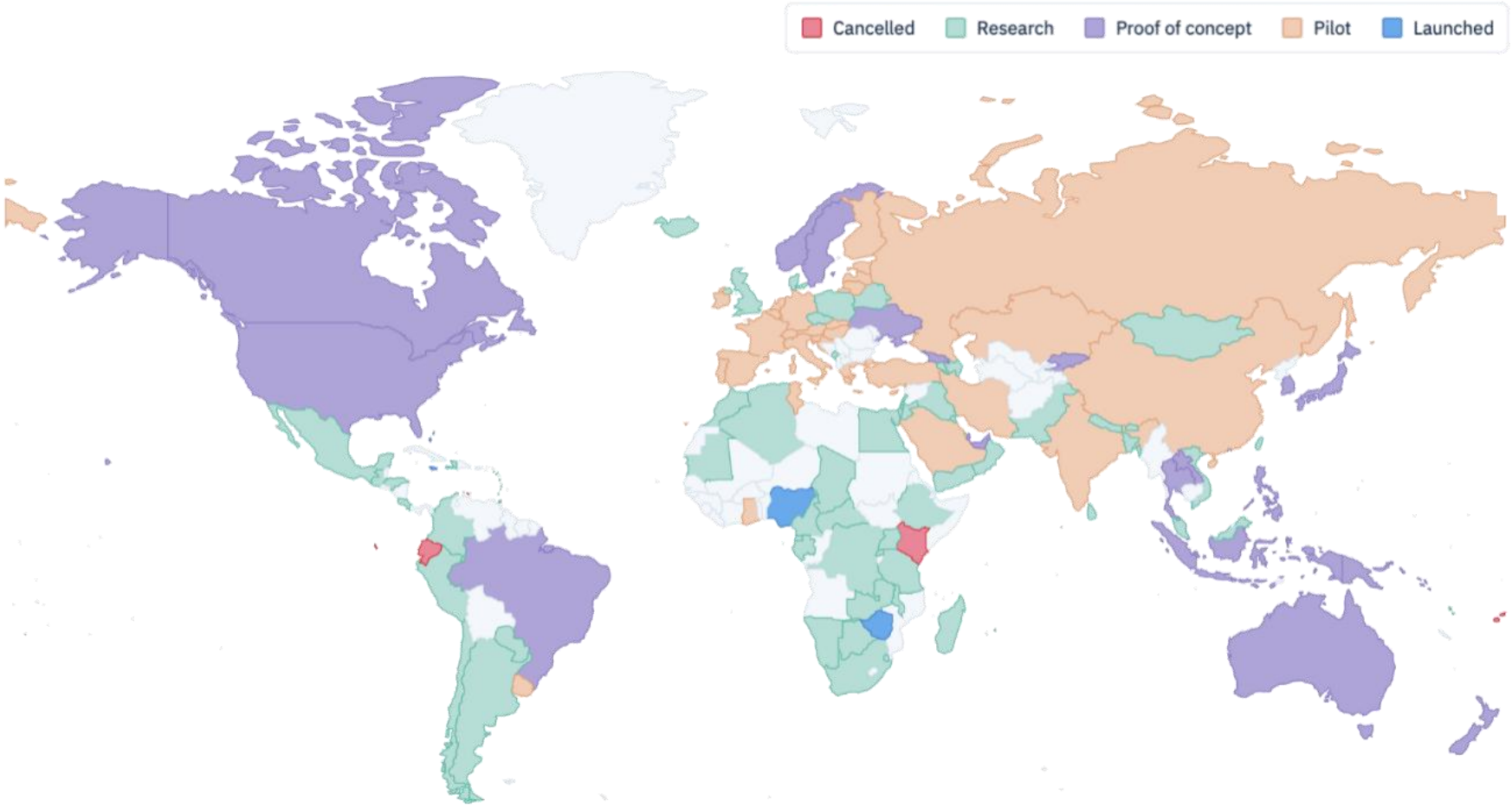
May 2020 *
35 countries and currency unions were exploring CBDCs

2025 *
134 countries and currency unions (~ 98% of global GDP) are exploring a CBDC

March 2025 *
65 countries are in the advanced phase of exploration - development, pilot, or launch

* Source: CBDC Tracker, March 2025

CBDCs Worldwide: Current Status *



Cancelled: Countires that cancelled or decommissioned a CBDC.

Research: Countries that have conducted first explanatory CBDC research.

Proof of Concept: Countries that are in an advanced research stage and have published a CBDC proof of concept.

Pilot: Countries that have developed a CBDC that is tested in a real environment either with a limited number of parties or on a wide scale.

Launched: Countries that officially fully launched a CBDC.

* Source: CBDC Tracker, March 2025

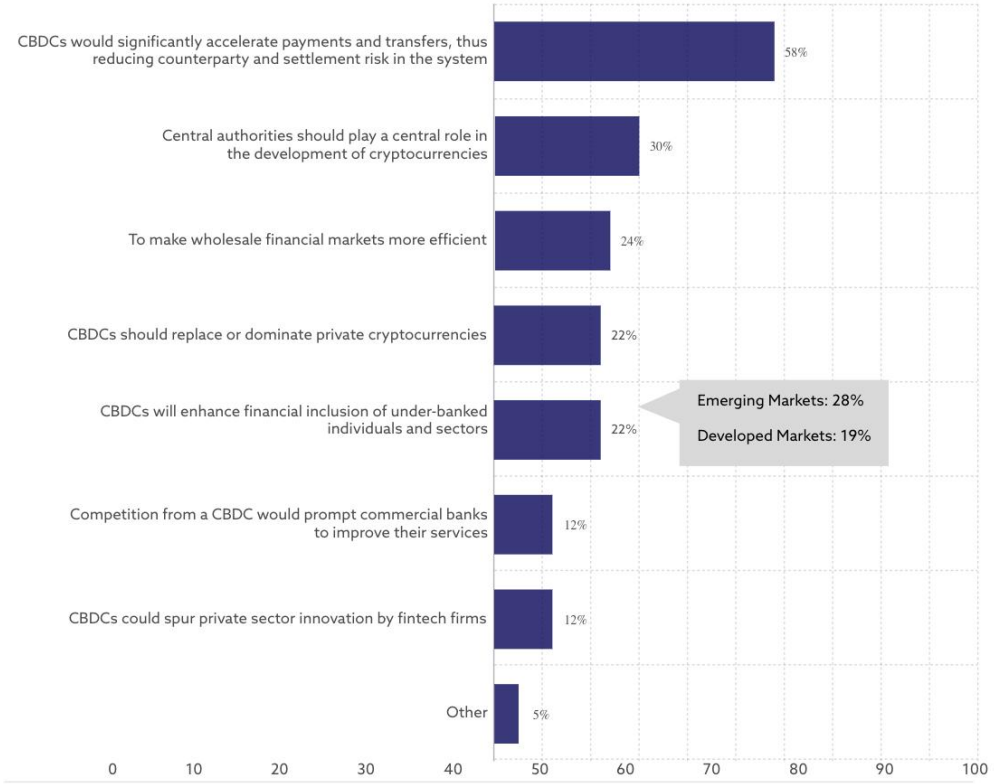
Global Exploration of CBDCs *

Digital currency	Country / Region	Central Bank(s)	Announcement Year	Status	Update rate
Wholesale Digital Euro	Euro Area	European Central Bank	2022	Pilot	
Digital Ruble	Russian Federation	Bank of Russia	2019	Pilot	
Papua New Guinea C...	Papua New Guinea	Central Bank of Papua New Guinea	2024	Proof of concept	
Namibia CBDC	Namibia	Bank of Namibia	2021	Research	
e-shekel	Israel	Bank of Israel	2023	Research	
E-cedi	Ghana	The Bank of Ghana	2018	Pilot	
Trigger Solution	Germany	Deutsche Bundesbank	2024	Pilot	
DREX	Brazil	Central Bank of Brazil	2017	Proof of concept	
Digital Dollar	United States of America	US Federal Reserve	2020	Cancelled	
Digital Pound	United Kingdom	Bank of England	2018	Research	

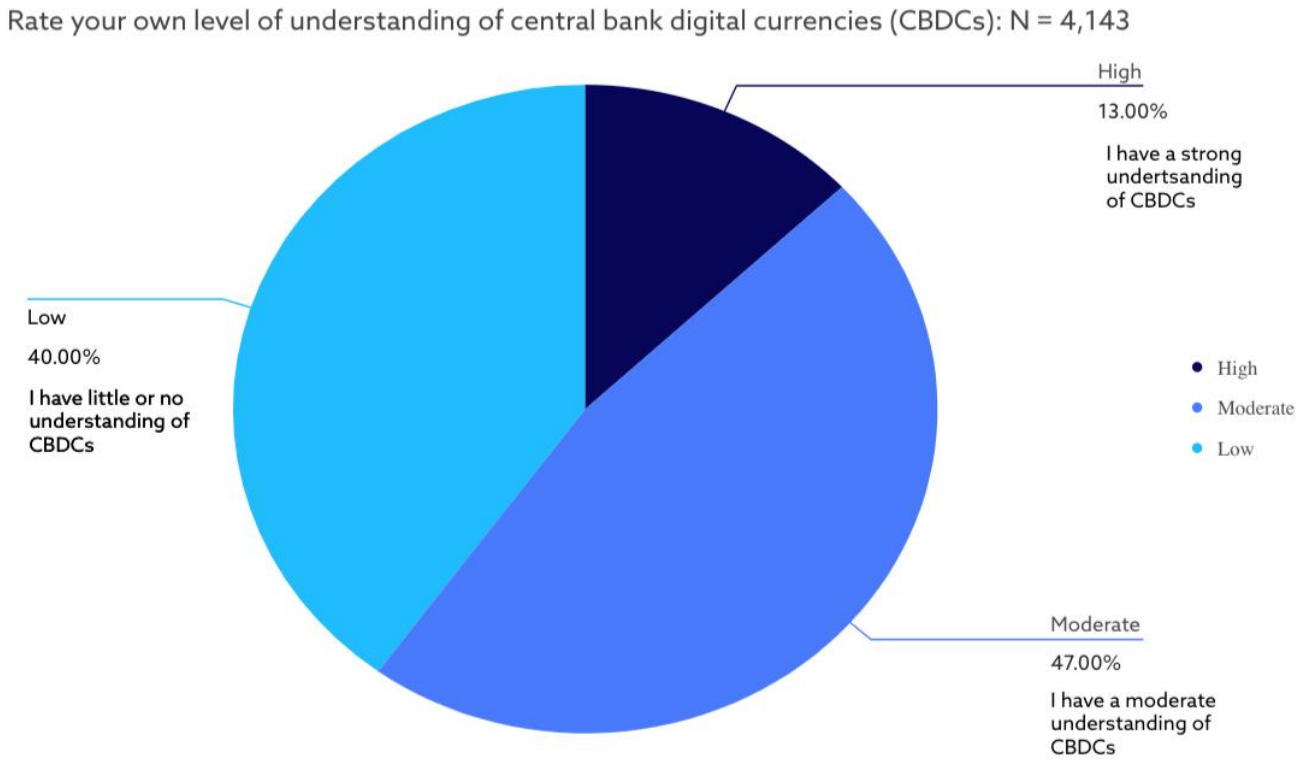
* Source: CBDC Tracker, March 2025

Global Exploration of CBDCs: CFA Institute

Why Should Banks Launch a CBDC?*



Level of Understanding of CBDCs (global results)*



* Source: CFA Institute Global Survey on Central Bank Digital Currencies, Available at https://www.cfainstitute.org/insights/articles/cbdcs-distinctions-between-wholesale-retail

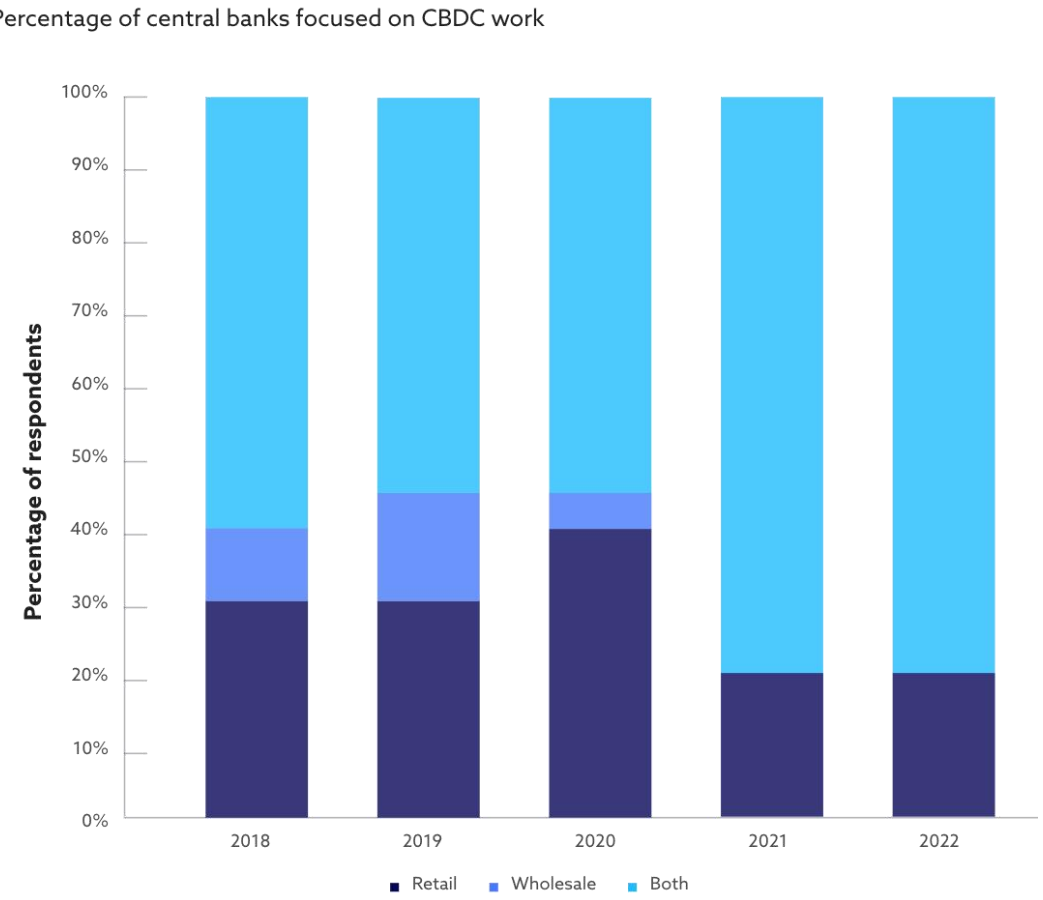
Types of CBDCs

wCBDCs **Wholesale CBDCs** are used among banks and other licensed financial institutions for interbank payments and securities transactions;

rCBDCs **Retail CBDCs** are a form of central bank digital currency that is used by the general public.

* Source: Deutsche Bank, 2023

CBDC Pilot Projects *



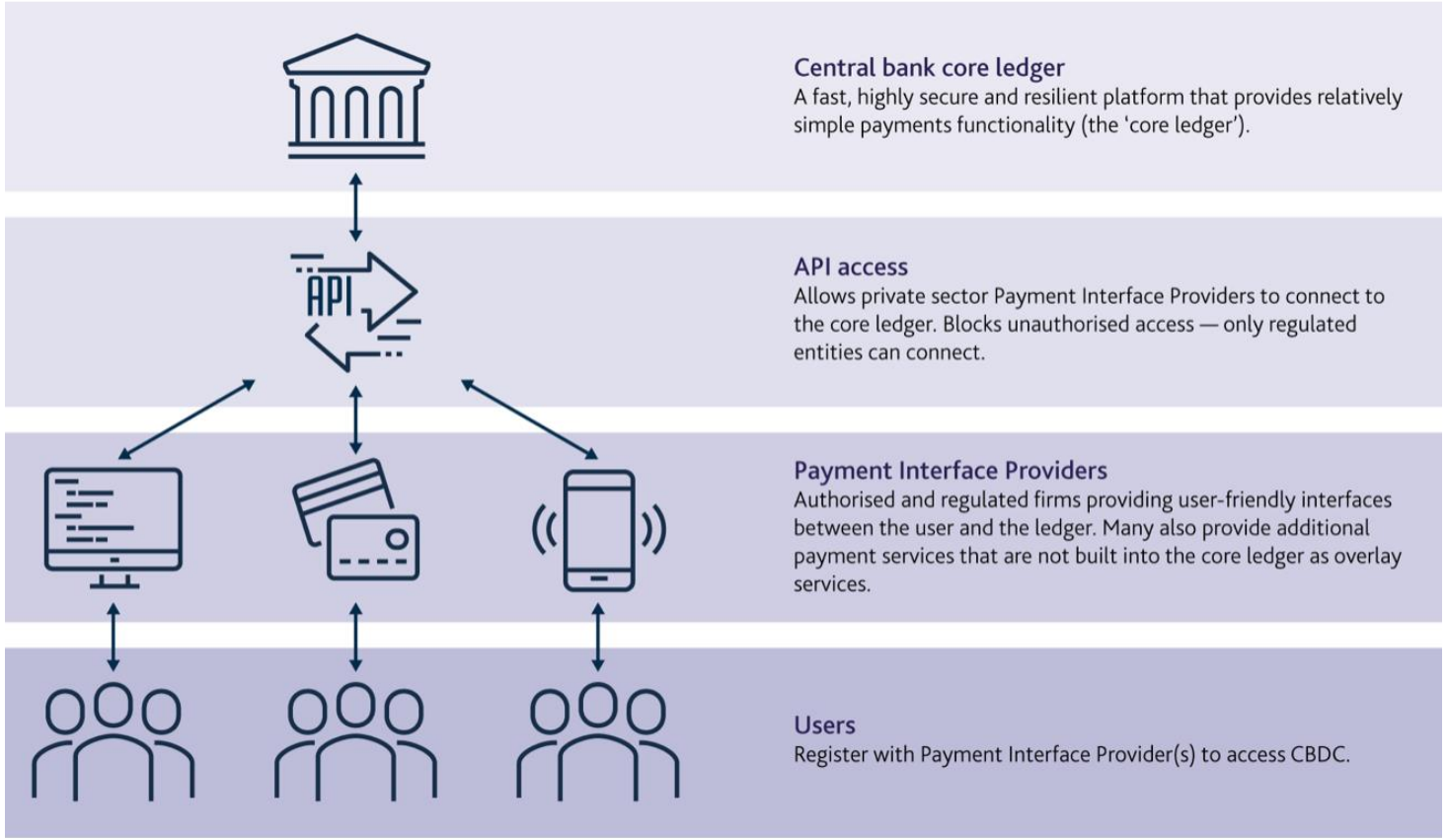
CBDCs Technology: Basic Terminology

The Digital Ledger's role is to record central bank liabilities and enable the minting of digital currencies.

Token is an object that represents something else, such as another object (either physical or virtual), or an abstract concept.

Digital record is a computerised version of an item of data.

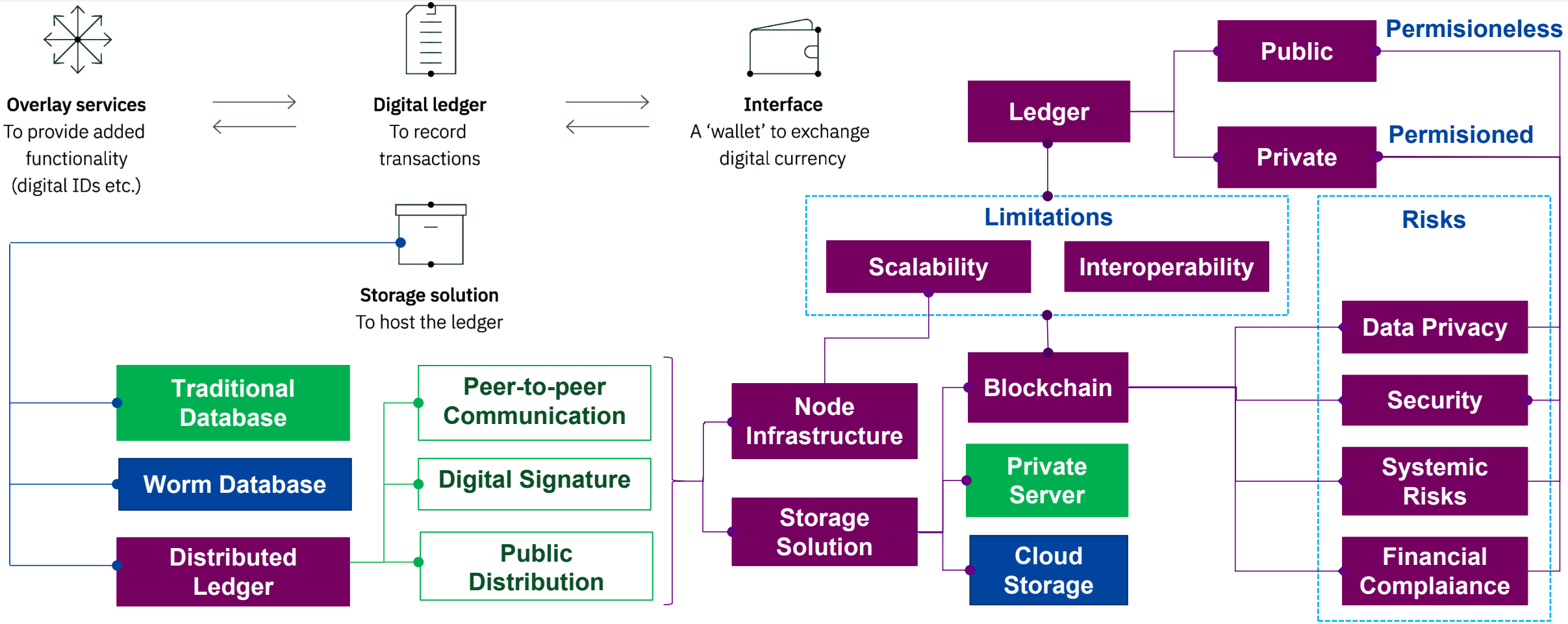
Example 1. Designing CBDCs: Platform Model*



'Platform' model of CBDC (March 2020): The central bank would build a fast, highly secure and resilient technology platform which would sit alongside our Real Time Gross Settlement (RTGS) service to provide the minimum necessary functionality for CBDC payments. This could serve as the platform to which private sector 'Payment Interface Providers' would connect in order to provide customer-facing CBDC payment services.

* Source: Bank of England, available at https://www.bankofengland.co.uk/paper/2020/central-bank-digital-currency-opportunities-challenges-and-design-discussion-paper

CBDCs Technology and IT Architecture*



* Source: Dr. Olga Khon (Ongoing Research, 2025)

CBDC Architecture: High-Level Technical Requirements **

Category	High-level technical requirements *	High-priority
Modular design	**Balance-keeping layer**	
	Allows for the creation, possession and destruction of CBDC	x
	Allows for flexible approach, issuing fungible tokens (type 1) and non-fungible tokens (type 2) for specific use cases	x
	Scalable databases (ledger-keeping infrastructure) to hold resources and on which settlements can be reflected	
	Connectivity between basic type 1 ledger and type 2 tokenisation infrastructure	

* Source: BIS, available at https://www.bis.org/publ/othp82.pdf

** Consultative Group on Innovation and the Digital Economy (CGIDE) established at the BIS Representative Office for the Americas

CBDC Architecture: High-Level Technical Requirements (2) **

Category	High-level technical requirements *	High-priority
Modular design	**Settlement layer**	
	Central banks can use parts of existing payment systems or can create a new platform that works in parallel to the existing system	x
	API infrastructure allows for consent and payment initiation	x
	Design of API infrastructure considers previous CGIDE work	x
	Settlement function is highly scalable in terms of the number of transactions, issuers and recipients	
	API infrastructure allows for information-sharing (balance and transactions)	
	Public wallet through an app that consumes the API architecture described above to serve as a backstop in case other solutions are unavailable	

* Source: BIS, available at https://www.bis.org/publ/othp82.pdf

** Consultative Group on Innovation and the Digital Economy (CGIDE) established at the BIS Representative Office for the Americas

CBDC Architecture: High-Level Technical Requirements (3) **

Category	High-level technical requirements *	High-priority
Core functions	**Issuance / destruction is centralised (only by the central bank)**	
	Issuance could be considered by transferring resources through the RTGS to an account held by the central bank for this purpose	x
	The previous step would allow for the creation of a token in the type 2 case or to increase the balance of the ledger for a type 1 solution	x
	For adequate destruction, tokens in the possession of the central bank are deleted (type 2) or the overall balance is reduced (type 1) solution	x
	The second step would imply the settlement of a transaction from the issuance account to the general account of the central bank	
	Both issuance and destruction could work for type 1 and type 2 solutions	

* Source: BIS, available at https://www.bis.org/publ/othp82.pdf

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CBDC Architecture: High-Level Technical Requirements (4) **

Category	High-level technical requirements *	High-priority
Core functions	**Transaction settlement**	
	Centralised in first stage (only the central bank's signature can validate transactions after checking ownership and no double spending)	
	Adaptable to allow for more signatures to the ecosystem (validate transactions through distributed consensus of approved signatures)	

* Source: BIS, available at https://www.bis.org/publ/othp82.pdf

** Consultative Group on Innovation and the Digital Economy (CGIDE) established at the BIS Representative Office for the Americas

CBDCs: System Design *

Element	Considerations and Trade-Offs
Privacy	
Laws, norms, and trust in institutions	These elements may vary in different jurisdictions. Therefore, the details of solutions will likely need to be tailored to local situations and needs even though the set of design options is common.
PETs	PETs are complex and differ in terms of their degree of privacy protection, computational burden and ease of implementation. For example, using computationally demanding PETs may increase transaction times and degrade the user experience.
Intermediaries	In jurisdictions that may choose to allow the behaviour, intermediaries may be incentivised to participate by being able to monetise users' information, such as the case in existing payment solutions. Balancing the incentivisation of a viable ecosystem with the need for privacy would need to be considered. While a two-tier model of private sector intermediaries is generally preferred, there may be reasons and benefits for a jurisdiction to have a public sector intermediary (not necessarily the central bank). In this arrangement a public intermediary may need to be held to a different data privacy standard than a private intermediary.

* Source: BIS Innovation Hub, available at https://www.bis.org/publ/othp88_system_design.pdf

CBDCs: System Design (2) *

Element	Considerations and Trade-Offs
Privacy	
Cost	Minimising data held at the central bank may raise the maintenance cost on intermediaries, potentially reducing their incentive to participate.
Financial Inclusion	For jurisdictions whose policy goals include being inclusive for people without sufficient identity for Know Your Customer (KYC), one potential solution may be to offer a non- registered CBDC. This may likely be constrained with holding and or transaction limits to reduce AML risks. Another consideration is the type of device.
Offline	One potential aspect of extended offline CBDC – where users can transfer funds offline for longer time periods (such as weeks or months) – is that these transactions are inherently not visible and therefore may not be traceable for compliance purposes. As with non-registered CBDC, limits to manage AML risk may need to be imposed.
Users	Allowing each user to determine the degree of privacy they would like – perhaps for benefits such as rewards by intermediaries – may be desirable in some jurisdictions. However, different levels of privacy may lead to engineering complexity.

* Source: BIS Innovation Hub, available at https://www.bis.org/publ/othp88_system_design.pdf

CBDCs: System Design (3) *

Element	Considerations and Trade-Offs
Cyber security	
Two-tier model	The two-tier model may create vulnerabilities, and central banks may have to strike a balance between imposing constraints for safety, while ensuring that intermediaries have the space to create value for themselves as well as their clients.
Standards	While the general assumption is that the standards for cyber security are expected to be extremely high, a more precise articulation by policy makers and risk managers would be required to make policy and system design choices.
Intermediaries	The contractual and oversight relationships with intermediaries, and technical controls placed on them to ensure security, may need to be coherent and balanced (trade-offs could arise between technical controls and oversight).
Quantum threat	The question of quantum safety is broader than CBDC, concerning the financial system at large. Risk and cyber security groups in many central banks are developing strategies for a post-quantum world, and some financial entities are collaborating with standard setting bodies. The investigation of the quantum threat by members in the context of CBDC would be applicable to other systems.

* Source: BIS Innovation Hub, available at https://www.bis.org/publ/othp88_system_design.pdf

CBDCs: System Design (4) *

Element	Considerations and Trade-Offs
Offline	
Utility / security	A key choice around managing risk may be whether funds will be settled offline and will be available for immediate forward use, or settled only when one of the parties eventually goes online.
Operational aspects	For example, updating devices in the field (older devices become vulnerable over time). The option of adding offline functionality separate to the main system may be considered.
Rules	Due to the possibility of loss of funds (from losing a device), rules around who bears the loss may have to be made clear.
Use cases	As demand for offline CBDC is unclear, it is difficult to solve for all possible use cases. As such, each jurisdiction may have to prioritize specific use cases for offline CBDC.
Point of Sale	
Compatibility with existing system	Design aspects that should be considered may include the contactless kernel (software which provides functions and processes that implement the business logic of a contactless transaction) to be used, transaction flow, the customer verification method, and the method to update wallet balances.

* Source: BIS Innovation Hub, available at https://www.bis.org/publ/othp88_system_design.pdf

Example 2. BIS Innovation Hub Projects on CBDC and Tokenisation *

	Helvetia	Jura	Genesis	Dunbar	mBridge	Dynamo
Main use case	Tokenised assets settlement in wholesale CBDC	Cross-border settlement with wholesale CBDC	Tokenised green bonds + delivery of carbon credits	International settlements using multiple CBDCs	Multilateral payments using multiple CBDCs	Smart contract programmability in trade finance
BIS IH Centre	Switzerland	Switzerland	Hong Kong SAR	Singapore	Hong Kong SAR	Hong Kong SAR
Participants	SNB	BDF, SNB	HKMA	MAS, SARB, RBA, BNM	HKMA, BOT, PBC, CBUAE	HKMA
Relevant currencies	CHF	EUR, CHF	HKD	AUD, MYR, SGD, SAR	HKD, CNY, THB, AED	HKD
PvP	✗	✓	✗	✓	✓	✗
DvP	✓	✓	✓	✗	✗	✗

PvP = payment versus payment; DvP = delivery versus payment.

BDF = Bank of France; BNM = Central Bank of Malaysia; BOT = Bank of Thailand; CBUAE = Central Bank of the United Arab Emirates; HKMA = Hong Kong Monetary Authority; MAS = Monetary Authority of Singapore; RBA = Reserve Bank of Australia; SARB = South African Reserve Bank; SNB = Swiss National Bank.

* Source: BIS (2023): "Blueprint for the future monetary system: improving the old, enabling the new", Annual Economic Report 2023, Chapter III, June, available at https://www.bis.org/publ/arpdf/ar2023e3.pdf

Stablecoins: Systemic Risks and Financial Stability

- **Stablecoins** are one of the types of derivative tokens issued (minted / burned) through smart contracts on blockchain networks.
- Due to the loopholes behind smart contracts' technology, stablecoins are prone to **boost systemic risks and cross-border illicit finance.**
- Smart contracts are tied to underlying blockchain and **do not exists outside or can't process off-chain data.**

Distributed Ledger Technology (DLT)

A Distributed ledger is a record of information, or database, that is shared across a network (European Central Bank*).

Payments and securities settlement systems are generally based on centralised infrastructures where market participants connect to a central database to settle transactions.

Distributed ledger technology is a new technological development where a database is shared across a network and its data is accessible to the network's members.

* Source: ECB, available at https://www.ecb.europa.eu/paym/integration/distributed/html/index.en.html

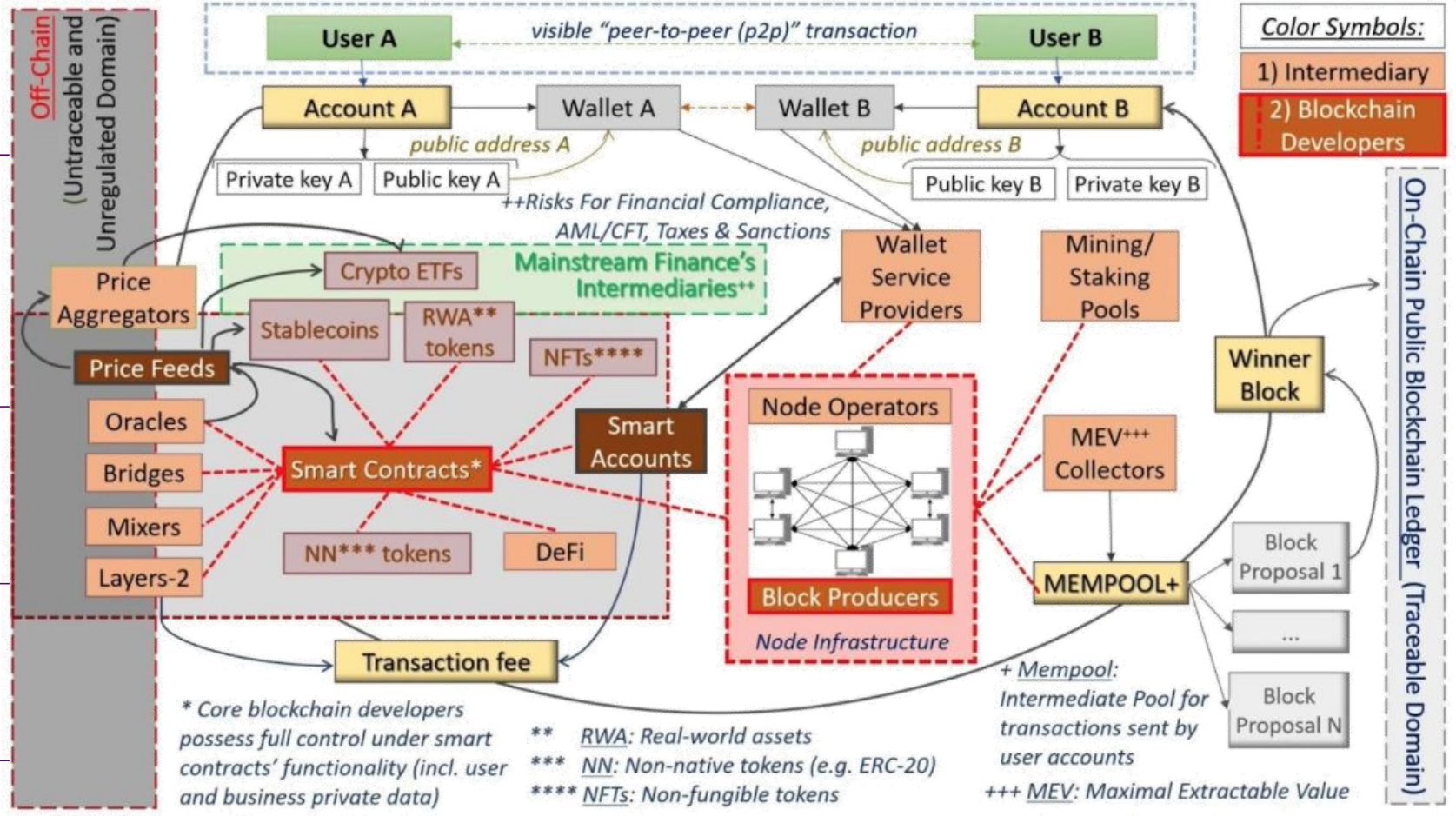
Distributed Ledger Technology (DLT) and Blockchain: Limitations and Risks over CBDCs *

Data Exposure to Unregulated Blockchain Developers and Third Parties

Poor Consumer Protection

Public Misguidance and Investor Fraud

Market Manipulation



* Source: Dr. Olga Khon (Ongoing Research, 2025)

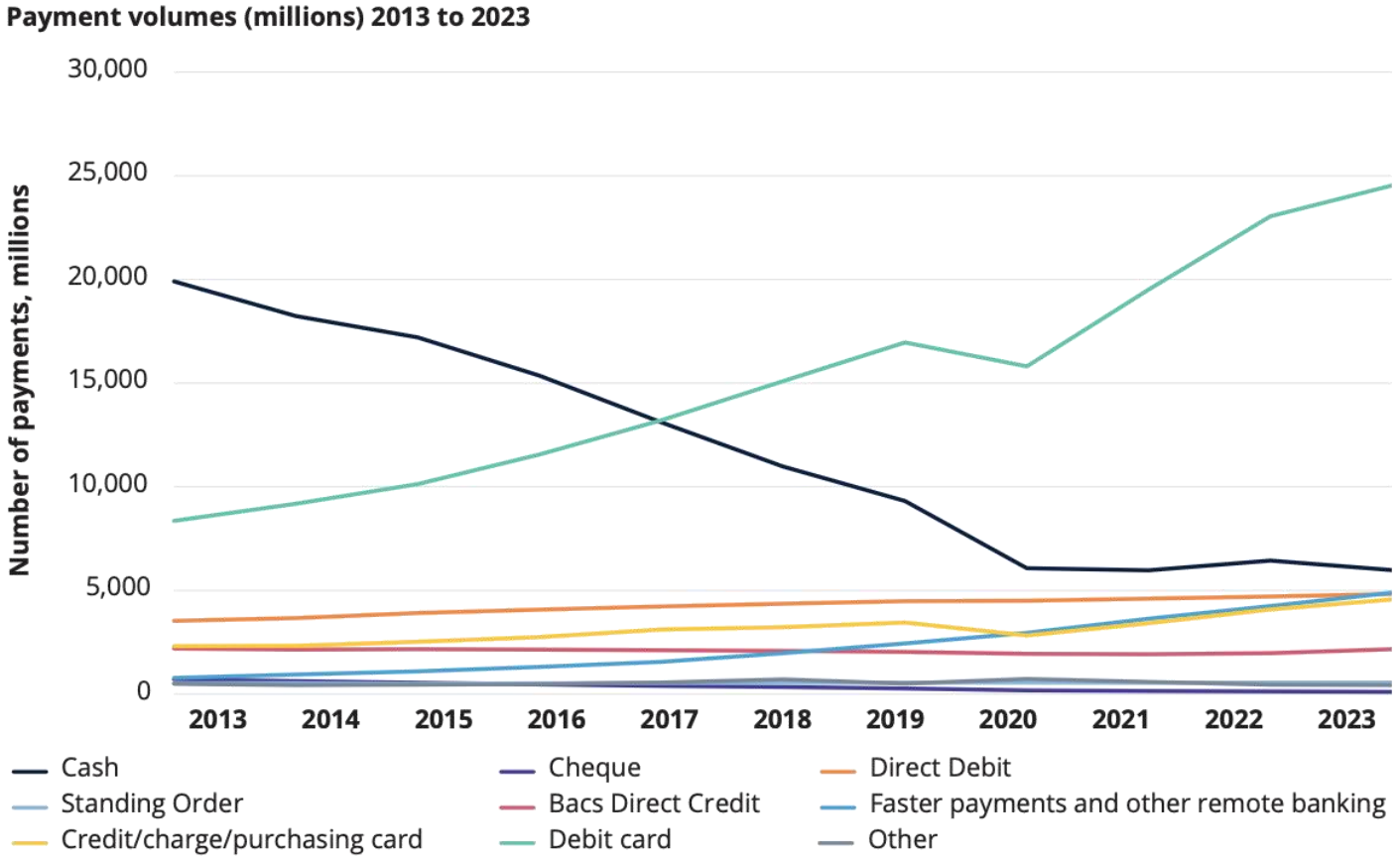
Stablecoins vs rCBDCs *

	rCBDCs *	Stablecoins *
Legal Tender	Legal tender	No legal tender
Reserves	Goverment-backed	1) Algorithmic (no reserves); 2) Collaterarized (privately-owned assets-backed)
Singleness of money	Singleness of money	No singleness of money
Underlying technology	State decision on an underlying IT arcitecture	Blockchain and Smart Contracts
Governance and funding	Public money	Private money
Financial stability	Preserve financial stability	Amplify systemic risks
Data privacy and security	Financial Regulators: Data disclosure in accordance with financial compliance and regulation	Unregulated Blockchain Developers: Full data exposure to blockchain developers

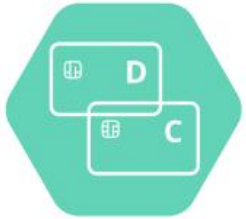
* Source: Dr. Olga Khon (Ongoing Research, 2025)

Payments in the UK

UK Finance Report 2024 **



payments made in 2023*



61%

In 2023 card payments accounted for 61% of all payments in the UK

66%

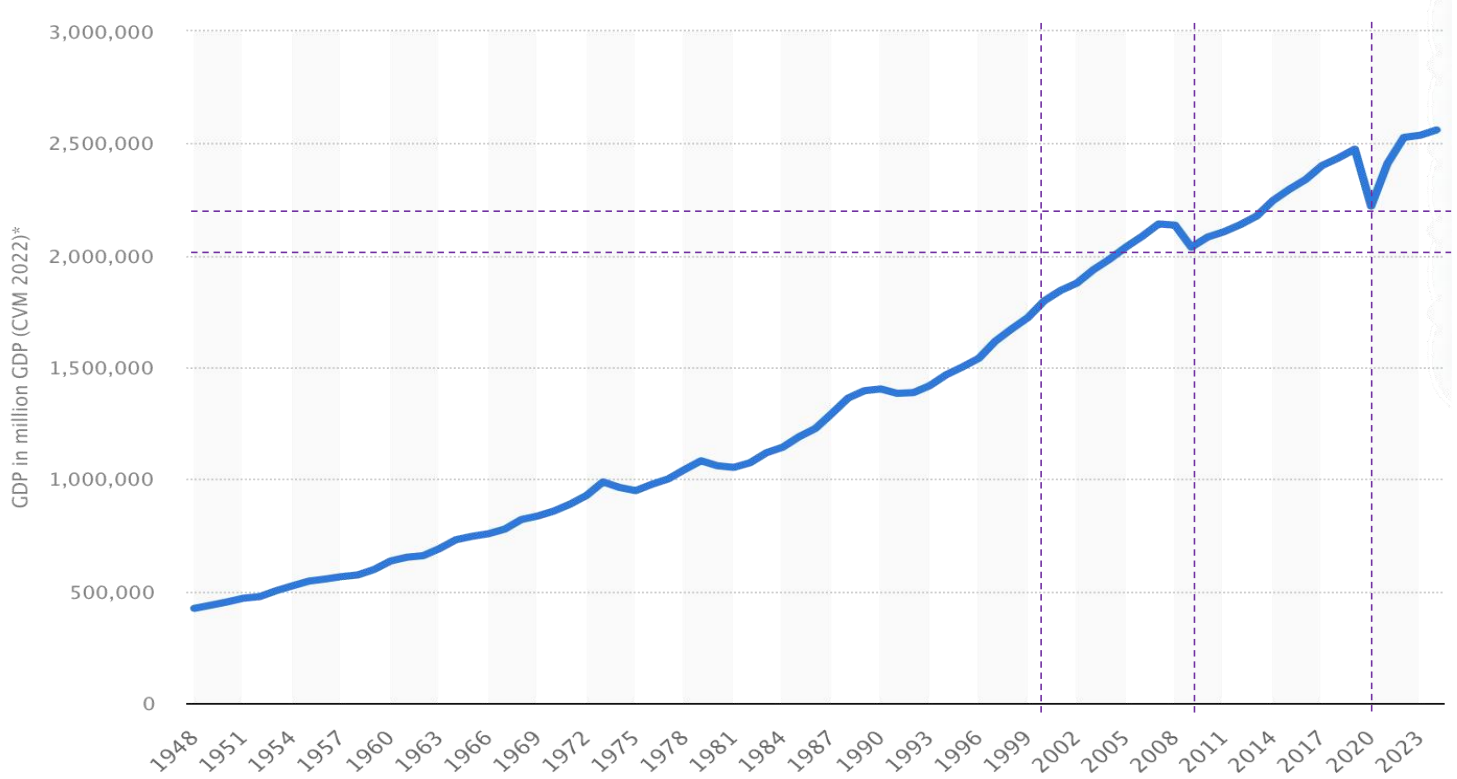
In 2033 card payments forecast to account for 66% of all payments in the UK

* Excluding CHAPS

** Source: UK Finance 2024 Report

Gross Domestic Product in the UK (1948-2024)

Gross Domestic Product in the UK, 1948-2024 *

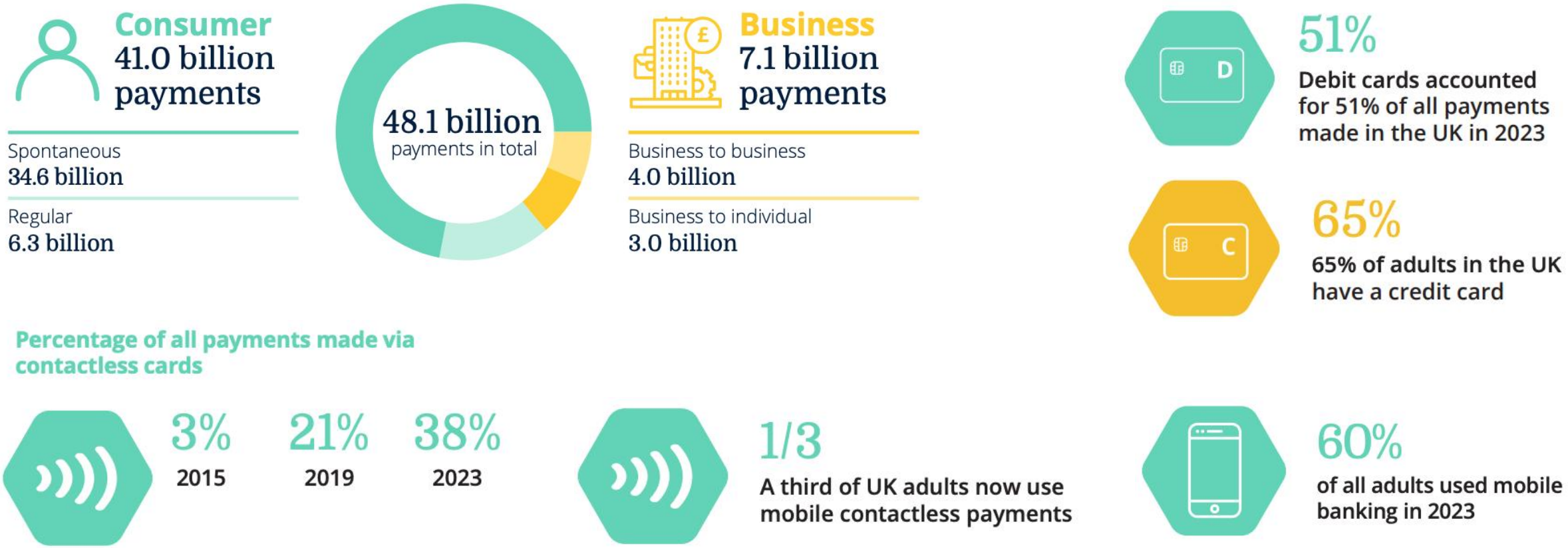


2023 UK GDP: £ 2,536 bln

2024 UK GDP: £ 2,560 bln

* Source: Statista 2025, available at https://www.statista.com/statistics/281744/gdp-of-the-united-kingdom/

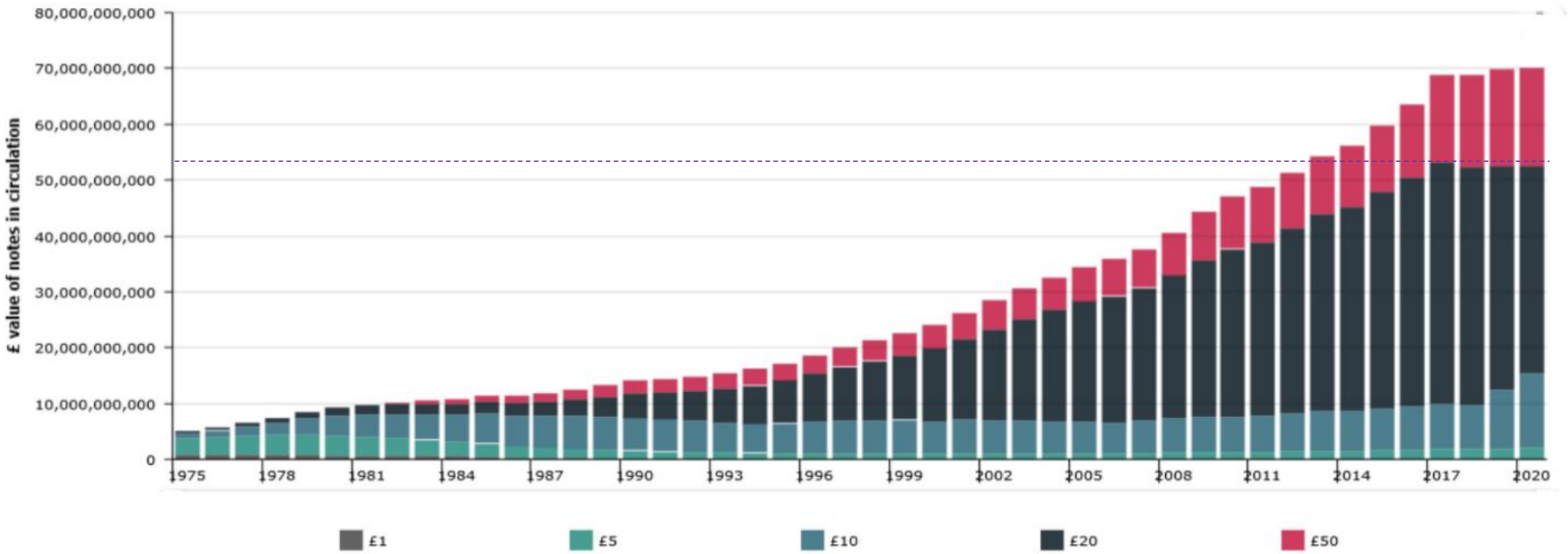
Consumer and Business Payments in the UK*



* Source: UK Finance 2024 Report

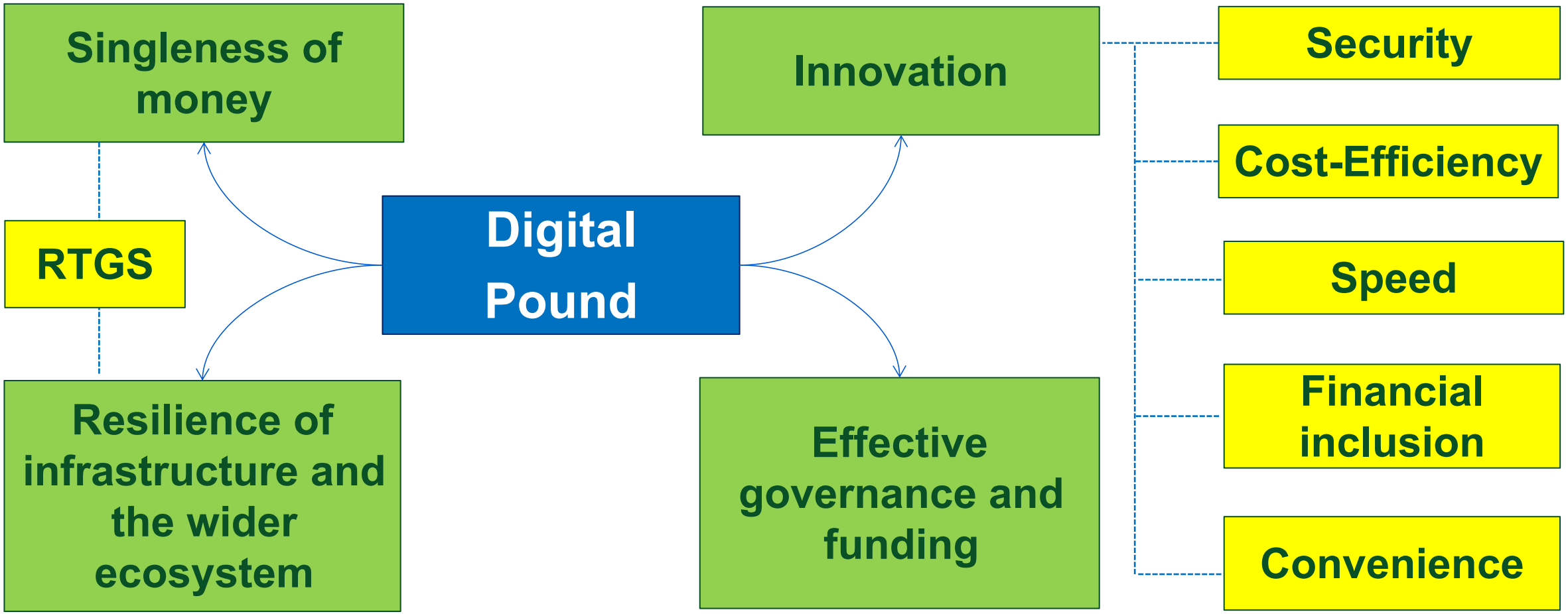
Payments in the UK: Notes in Circulation

Notes in Circulation in the UK, 1975 - 2020 *



* Source: PSR based on Bank of England data

Digital Pound: BoE Progress Update 2025



Digital Pound: BoE Progress Update 2025*(2)

Outcome	Retail Payments and Money
1. Singleness of money	The design, operation and supervision of retail payment systems must support confidence in the one-for-one exchange between central bank money and private money. All different forms of money must be exchangeable with each other at par value and at all times. Any new retail payment systems must be interoperable with Real-Time Gross Settlement (RTGS) as the UK's core payments and settlement infrastructure.
2. Innovation	The retail payments ecosystem and the regulatory environment must support safe and sustainable innovation in payments, consistent with the UK retaining its place within a competitive global financial system while also reducing the potential for disruption. Payments made on programmable platforms should be available to consumers. As part of this, payments infrastructure should enable new entrants to provide payment services without those entities having the means to issue money. UK retail payments systems should have the functionality to be able to communicate and interoperate with overseas equivalents in cross-border payments.

* Source: Bank of England, Progress Update, January 2025.
Available at https://www.bankofengland.co.uk/report/2025/digital-pound-progress-update

Digital Pound: BoE Progress Update 2025*(3)

Outcome	Retail Payments and Money
3. Resilience of infrastructure and the wider ecosystem	There must be end-to-end resilience across the payments chain for retail payments. This includes the need for agile risk management frameworks that enable providers to respond to emerging threats. Policymakers must also have the tools to address single points of failure arising from concentration in service provision at critical points in the chain, for instance through expanding the Bank of England's regulatory payments perimeter.
4. Effective governance and funding	Payment systems must have governance frameworks that reflect the views of direct and indirect users of the infrastructure and enable effective supervision. Regulations and financial market infrastructure rulebooks must keep pace with a changing consumer landscape to maintain public confidence in payment systems. This includes tackling authorised push payment (APP) scams through better prevention and detection as well as appropriate consumer protection arrangements. Infrastructure providers must have sustainable and coherent funding and revenue models to ensure they can invest in their resilience and modernisation.

* Source: Bank of England, Progress Update, January 2025.
Available at https://www.bankofengland.co.uk/report/2025/digital-pound-progress-update

Payment System in the UK: Cross-Border Payments*

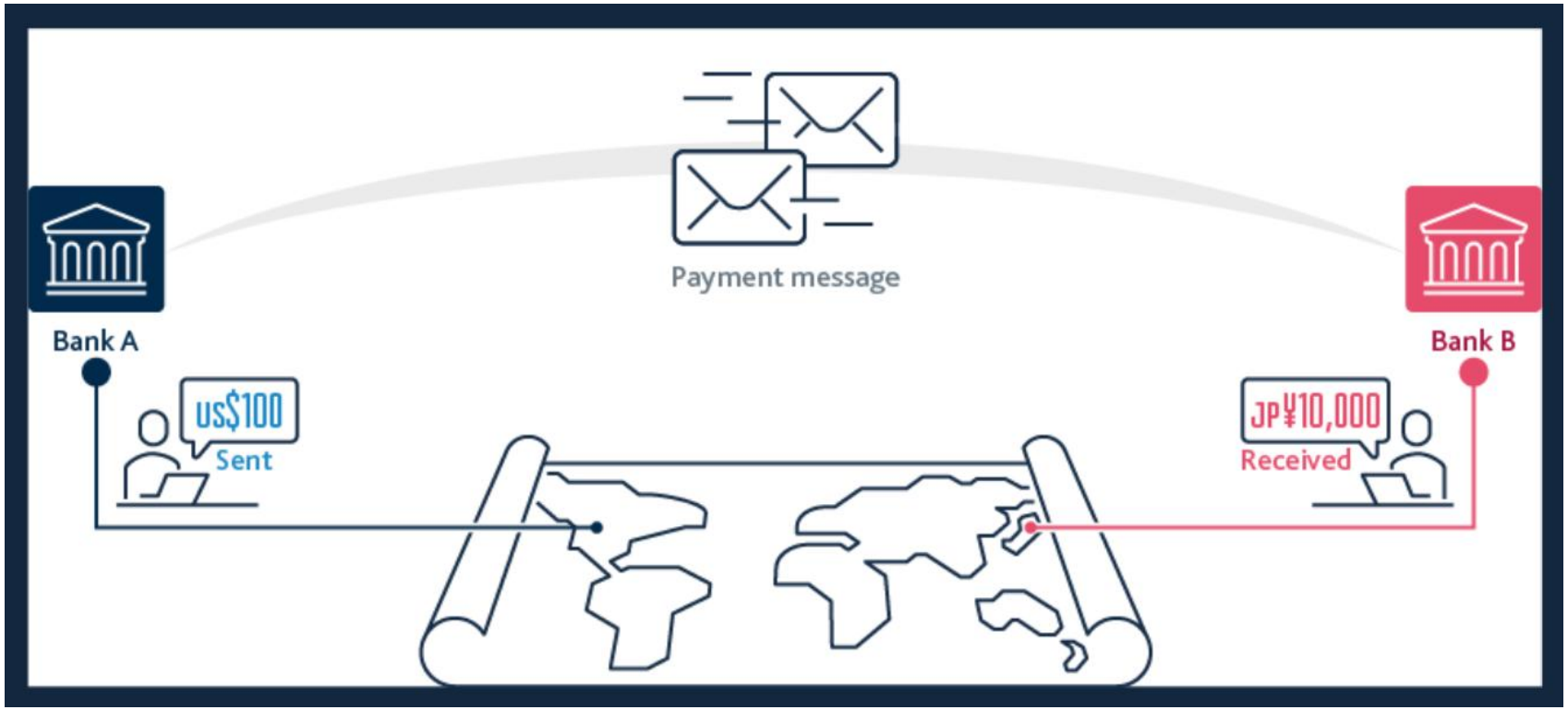
Cross-border payments are financial transactions where the payer and the recipient are based in separate countries. They cover both wholesale and retail payments, including remittances.

Cross-border payments can be made in several different ways. **Bank transfers**, **credit card payments** and alternative payment methods such as **e-money wallets** and **mobile payments** are currently the most prevalent ways of transferring funds across borders.

* Source: Bank of England, available at https://www.bankofengland.co.uk/payment-and-settlement/cross-border-payments

Payment System in the UK: Cross-Border Payments (2)*

Example 3. A simple cross-border payment using accounts held at each bank:

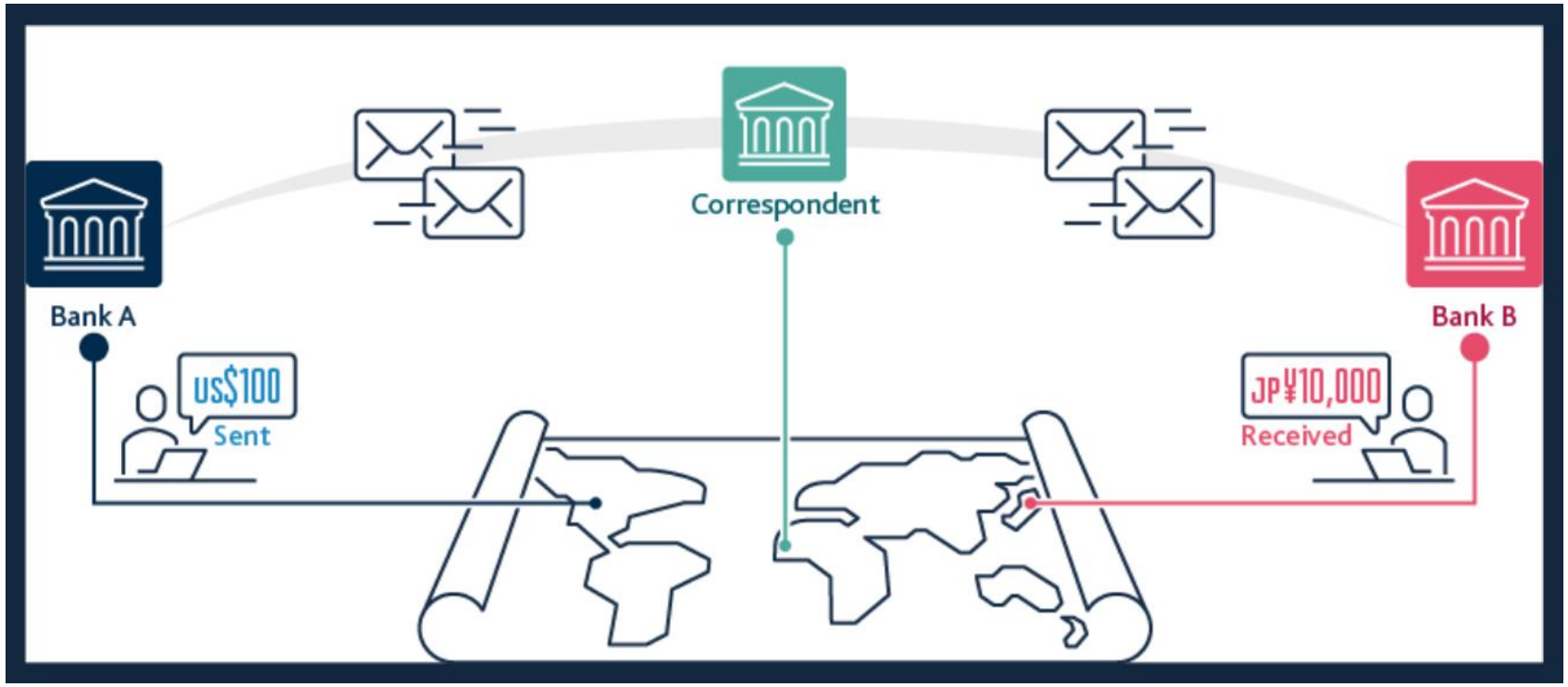


A payment message sends an instruction to debit an account in Bank A and credit an account in Bank B.

* Source: Bank of England, available at https://www.bankofengland.co.uk/payment-and-settlement/cross-border-payments

Payment System in the UK: Cross-Border Payments (3)*

Example 4. A cross-border payment using a correspondent bank:

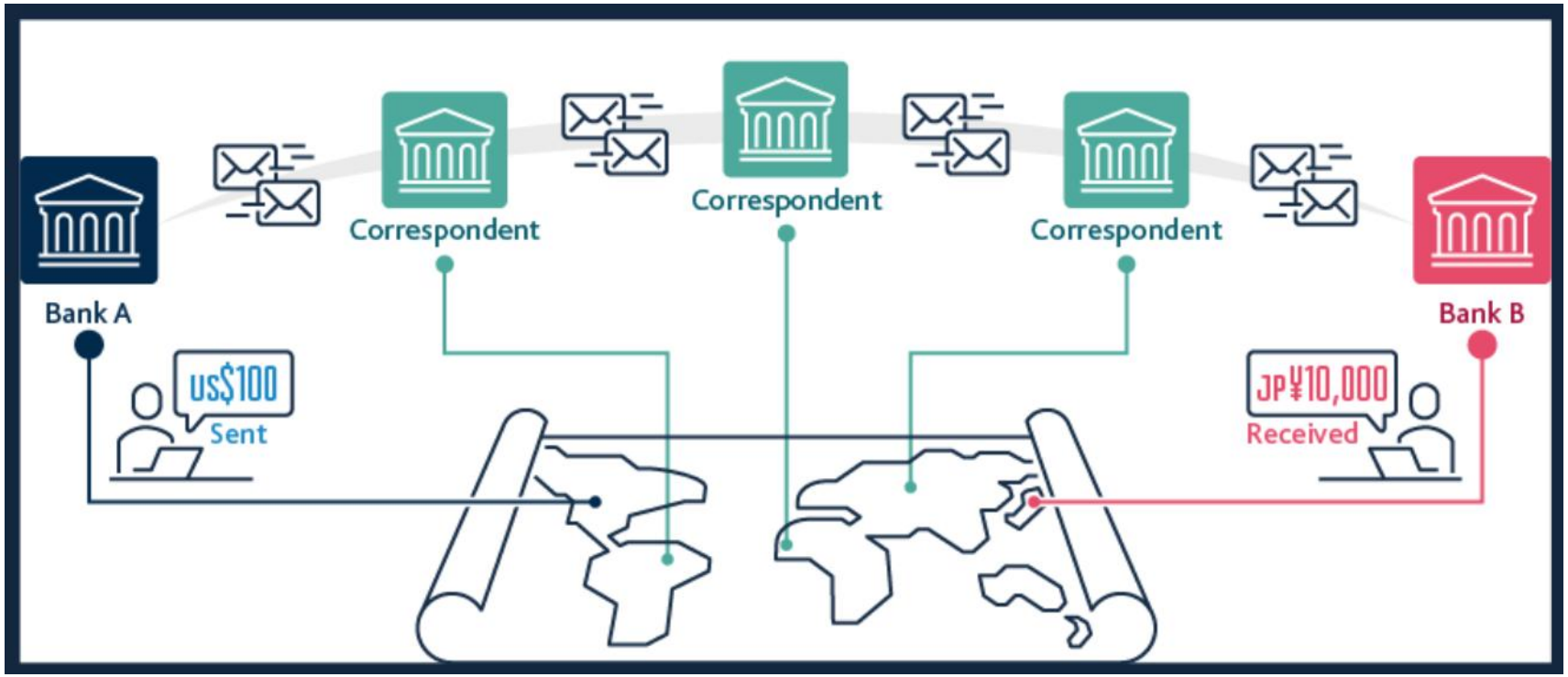


Bank A and Bank B do not have accounts with each other so they use a bank where they both hold accounts — the correspondent bank.

* Source: Bank of England, available at https://www.bankofengland.co.uk/payment-and-settlement/cross-border-payments

Payment System in the UK: Cross-Border Payments (4)*

Example 5. Cross-border payment using the correspondent-banking network:

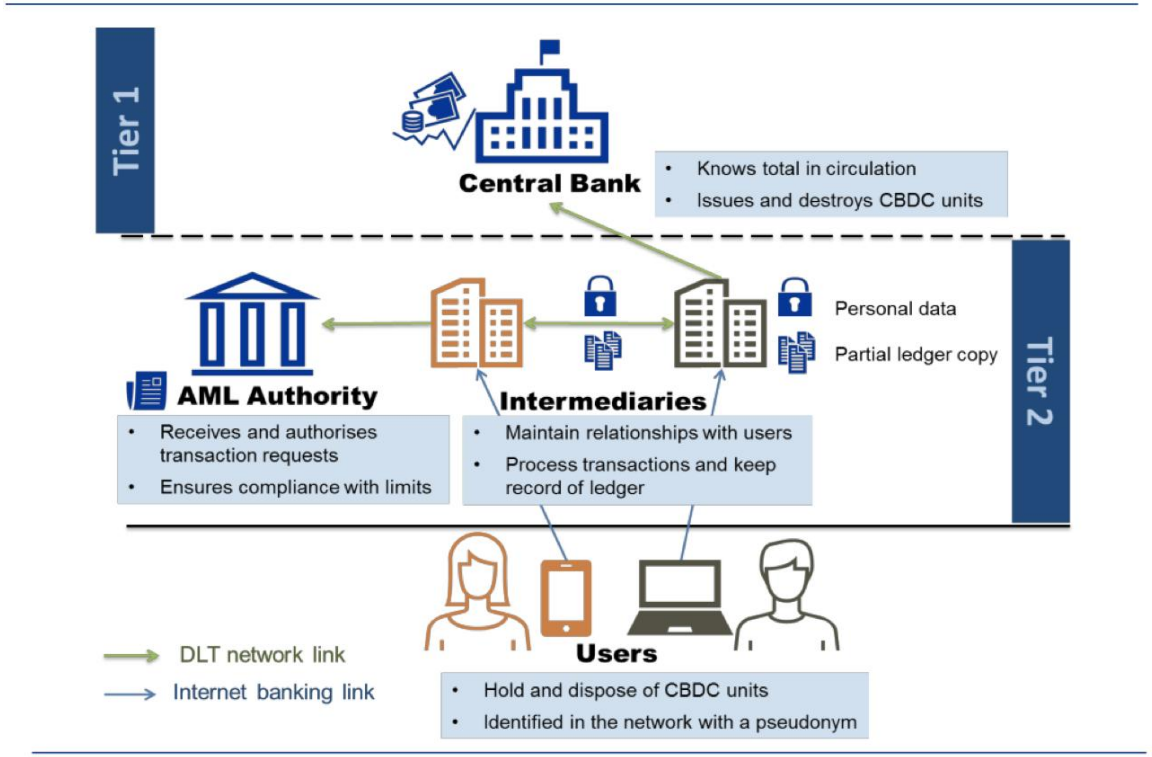


The less common the currency pair, the more correspondent banks will be required to make the payment, incurring costs and delays at each stage.

* Source: Bank of England, available at https://www.bankofengland.co.uk/payment-and-settlement/cross-border-payments

Case 2. ECB's CBDC (Digital EURO): Proof-of-Concept on Corda

Example 6. Two-tier model and relationship between entities

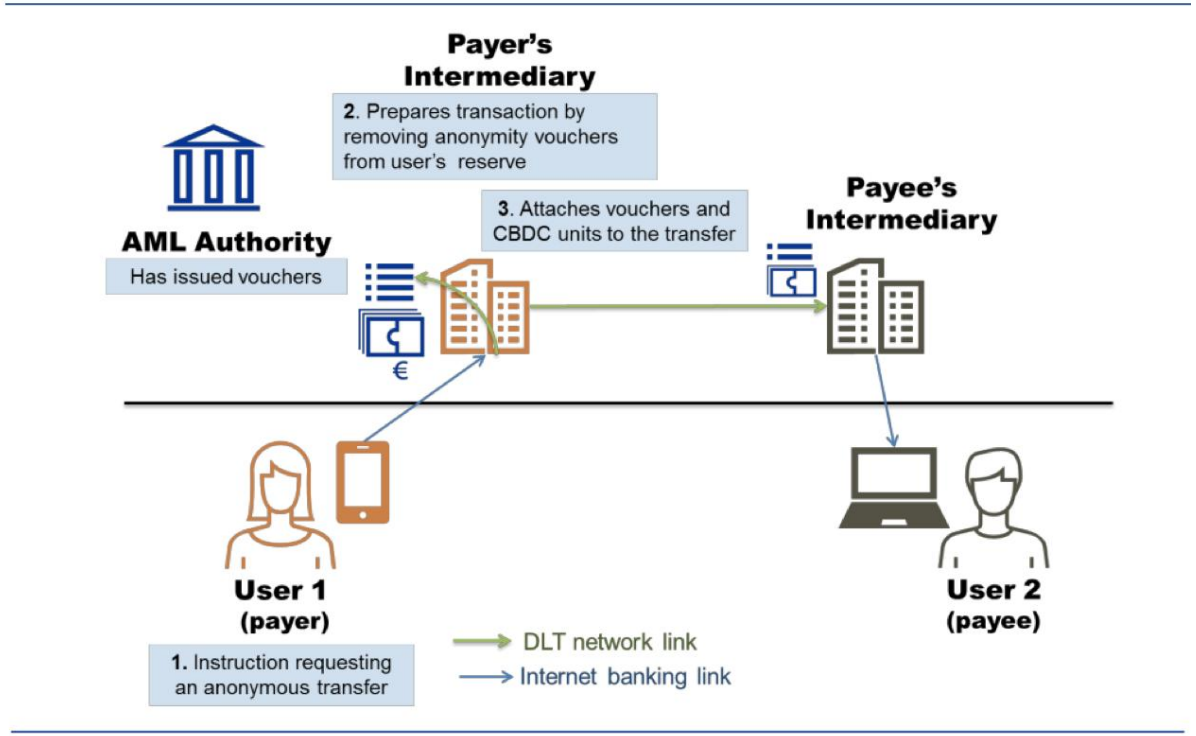


Corda is a DLT platform which is designed to ensure that the information that is held locally by two users, which store details of their bilateral transactions, is consistent with the overall information stored in the system (without that information being shared with other users)

* Source: European Central Bank, available at https://www.ecb.europa.eu/press/intro/publications/pdf/ecb.mipinfocus191217.en.pdf

Case 2. ECB's CBDC (Digital EURO): Proof-of-Concept on Corda (2)

Example 7. Transfer with anonymity vouchers

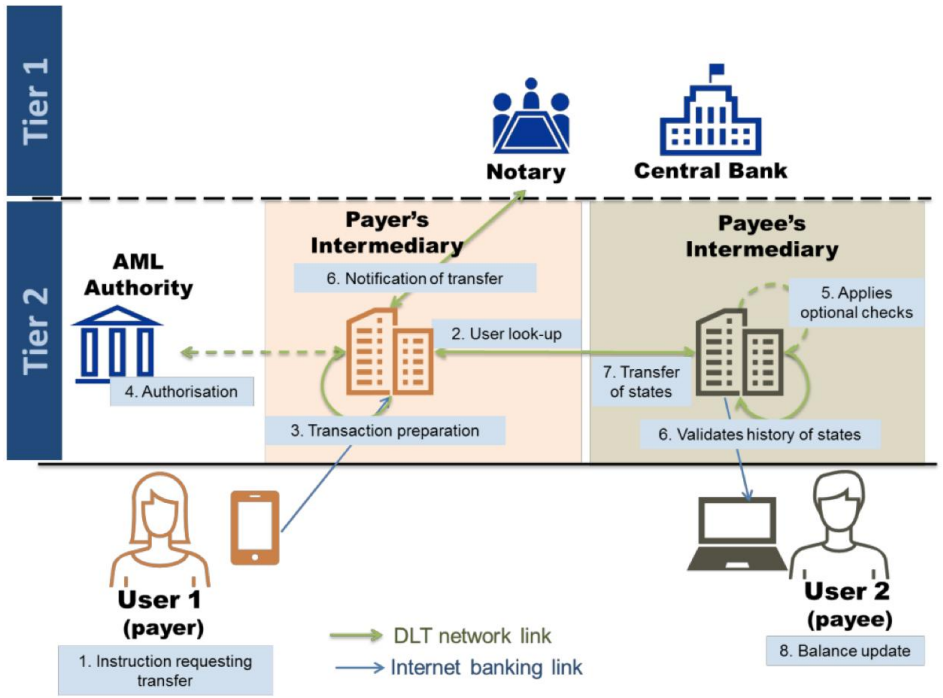


The payer's intermediary removes the necessary vouchers from the user's reserves and attaches them to the transfer of CBDC, to prove to the payee's intermediary that the transaction can be validated without checks being carried out by the AML authority

* Source: European Central Bank, available at https://www.ecb.europa.eu/press/intro/publications/pdf/ecb.mipinfocus191217.en.pdf

Case 2. ECB's CBDC (Digital EURO): Proof-of-Concept on Corda (3)

Example 8. Transfer with AML checks



If a payer chooses not to use vouchers or does not have enough vouchers available, its intermediary will prepare the transfer and route it via the AML authority, sending additional information on the payer for the necessary AML checks. The AML authority will either approve or reject the transfer. The payee's intermediary will only accept the payment if it is approved by the AML authority.

* Source: European Central Bank, available at https://www.ecb.europa.eu/press/intro/publications/pdf/ecb.mipinfocus191217.en.pdf

DLT and Mainstream Finance: Default Limitations

1. Interoperability and Financial Stability

In the CFA Institute's CBDC survey, conducted in February 2023, 69% of respondents said compatibility with other international networks and payments platforms should be a priority for a CBDC.

2. Scalability, Data Privacy and Security

3. Programmability and Financial Compliance

4. Anonymity/Pseudonymity and AML Policices

5. Immutability and DLT Exposure

Research Activity 1. Brainstorming: The Cross-Border and Regional Level of CBDC's Projects

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Steps to follow:

1. Choose the ongoing CBDC project;
2. Conduct research anaylsis of the selected project;
3. Present the summary of the current state of the project:
    - Identify advantages, challenges and perspectives of the project;
    - Clarify the project's technological solutions and choices of IT architecture;
    - Apply secondary data to present the evidence for your conclusions.

Q&A

Thank you!