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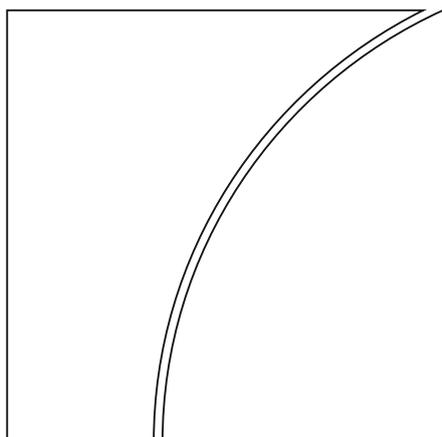
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Finternet: the financial system for the future

by Agustín Carstens and Nandan Nilekani

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Finternet: the financial system for the future

Agustín Carstens and Nandan Nilekani^{1, 2}

Abstract

This paper lays out a vision for the Finternet: multiple financial ecosystems interconnected with each other, much like the internet, designed to empower individuals and businesses by placing them at the centre of their financial lives. It advocates for a user-centric approach that lowers barriers between financial services and systems, thus promoting access for all. The envisioned system leverages innovative technologies such as tokenisation and unified ledgers, underpinned by a robust economic and regulatory framework, to dramatically expand the range and quality of financial services. This integration aims to foster greater participation, offer more personalised services and improve speed and reliability, all while reducing costs for end users. Most of the technology needed to achieve this vision exists and is fast improving, driven by efforts around the world. This paper provides a blueprint for how key technical characteristics like interoperability, verifiability, programmability, immutability, finality, evolvability, modularity, scalability, security and privacy can be incorporated, and how varied governance norms can be embedded. Delivering this vision requires proactive collaboration between public authorities and private sector institutions. The paper serves as a call for action for these entities to establish a strong foundation. This would pave the way for a user-centric, unified and universal financial ecosystem brought into the digital era that is inclusive, innovative, participatory, accessible and affordable, and leaves no one behind.

Keywords: payment systems, financial system, financial intermediaries, financial instruments, currency, digital innovation, unified ledgers, tokenisation.

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¹ Carstens: Bank for International Settlements (BIS), Nilekani: Unique Identification Authority of India (UIDAI) (Aadhaar) and Foundation for Interoperability in the Digital Economy (FIDE). The views expressed are those of the authors and not necessarily those of the BIS, UIDAI or FIDE.

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1. Introduction

In recent decades, advances in digital technology have transformed our lives. We see the consequences everywhere: in the way we shop, in how we consume news and entertainment and in our interactions with friends, family and colleagues. Tasks that were once expensive, complex and time-consuming, like making an overseas phone call or booking a hotel room in an unfamiliar city, can now be done with the flick of a finger.

Glimpses of the potential of digital innovation are also apparent in the financial system. The widespread deployment of mobile and fast payment systems has made the act of buying goods and services – perhaps the most ubiquitous financial transaction – easier, cheaper and more secure. Meanwhile, in some jurisdictions, verifiable digital identity systems have helped hundreds of millions of people to open bank accounts, build savings, insure themselves and access loans for the first time.

But there are too few of these examples. Large swathes of the financial system are stuck in the past. Many transactions still take days to complete and rely on time-consuming clearing, messaging and settlement systems. Some even involve physical paper trails. Even within countries, a lack of adaptive interconnectedness means that different parts of the financial system often do not talk to each other. The barriers to transactions that cross national borders are larger still.

The failure to develop a modern financial system has many costs. Some are visible: transferring assets takes too long, fails too often and costs too much. Others are hidden: beneficial activities do not take place, and access to financial services is needlessly limited by a financial system dominated by legacy systems.

The costs of an antiquated financial system are particularly stark in emerging market and developing economies (EMDEs). For many of their residents, financial services are not merely sub-standard, but not available at all. As a result, they still use cash as their only means of payment, borrow from informal sources and save their money “under the mattress”. Lack of access to financial services prevents people from increasing their incomes, improving their skills, expanding their opportunities and making full use of the digital economy.

To build a financial system fit for the future, we need to agree on the vision we want to achieve. In this paper, we propose the concept of the “Finternet”: multiple financial ecosystems interconnected with each other, much like the internet, designed to empower individuals and businesses by placing them at the centre of their financial lives. It would lower barriers between different financial services and systems, drastically reducing the complex clearing and messaging chains and other frictions that hinder today’s financial system. According to our vision, individuals and businesses would be able to transfer any financial asset they like, in any amount, at any time, using any device, to anyone else, anywhere in the world. Financial transactions would be cheap, secure and near-instantaneous. And they would be available to anyone, ensuring financial inclusion by meeting the needs of currently underserved segments of the population. Compared with what is available today, the Finternet would offer broader access, better risk management, increased information availability and lower transaction costs. New, personalised financial services would emerge, fostering more “complete” markets and improving welfare.

Such a vision is ambitious. Some aspects may be unattainable. But the potential gains are enormous. Hence, we should do all we can to turn it into reality.

The good news is that much of the technology to deliver a better financial system is there. We can represent financial assets – whether they be money, shares, bonds, real estate or insurance contracts – in digital form. We can send those assets around the world with the push of a button. And we can use digital tools to verify instantaneously and with certainty that the individuals and businesses involved in transactions comply with all relevant laws and regulations.

What we lack is the means to bring the various components of the financial system together. Financial ecosystems contain many moving parts. Individual participants seeking to break down silos and realise efficiencies face a daunting array of legal, regulatory and institutional hurdles. The benefits of a more efficient financial system would be distributed broadly, not least to individuals and small businesses through lower costs, more choice and better services. But the rents from maintaining existing barriers are quite concentrated. As a result, changes to the financial system, when they are eventually made, tend to be gradual and piecemeal. Improvements in processes, systems and infrastructure are constrained by the need to account for legacy architecture where progress has not been so rapid. There is thus a strong rationale for public authorities to play a catalytic role, working with private sector counterparts to assemble the complete financial, technological and governance architecture needed to bring the future financial system into being (see Box A).

“Unified ledgers”, an important building block of the Finternet, are a promising vehicle to turn our vision of an efficient future financial system into reality. These are digital platforms that bring together multiple financial asset markets – such as for wholesale tokenised central bank money, tokenised commercial bank deposits and other tokenised assets, including company shares, corporate or government bonds and real estate, to name just a few – as executable objects on common programmable platforms. In doing so, unified ledgers would provide an economic and financial architecture to realise the full potential of tokenisation and other novel financial technologies, supported by robust legal and governance arrangements and modern technological underpinnings. Once on a ledger, assets could be transferred immediately, safely and securely, with less reliance on the external verification processes or messaging systems that make today’s financial system so costly, slow and, in some cases, unreliable. Grounded on a digital-first approach and leveraging tokenisation, unified ledgers would improve existing financial transactions, by making them cheaper, faster and safer. They would also make entirely new financial products and transactions possible.

While the Finternet, including unified ledgers, offers benefits to all economies, there are particular benefits in EMDEs. These are the jurisdictions where access to and use of financial and payment products is currently most circumscribed. And they are the ones where the gains from using new technologies to broaden participation in economic activity and to provide new opportunities for individuals to invest, to protect themselves through insurance and to ensure the safe custody of their assets is the greatest.

Bridging the gap between vision and reality will be a challenge. The coordination problems and vested interests that hinder improvements to existing financial infrastructures will also need to be overcome to deploy entirely new ones. Institutions looking to foster the development of unified ledgers and associated financial architectures will need to decide where to start and how to make the inevitable compromises to get things moving without sacrificing bigger gains in the future. The existence of these challenges is not cause for delay, however. Rather, it increases the urgency to take the first steps by experimenting and exploring alternative approaches.

In this paper, we lay out a blueprint to help public authorities and private institutions take the first step. In Section 2, we first lay out our vision for the Finternet and describe how recent advances in digital technology could help bring it to fruition. In Section 3, we describe the economic rationale for unified ledgers – a promising vehicle to turn our vision of the future financial system into reality – as well as the technical, regulatory and legal building blocks needed to bring the ledgers together. Section 4 proposes eight fundamental design considerations that we feel must be a core part of the Finternet. That said, we acknowledge upfront that there can be no one-size-fits-all solution. Each jurisdiction will need to chart its own course to build the Finternet, based on its own laws, regulations and the existing state of the financial system. Section 5 concludes.

Now is the right time for the Finternet

The financial services landscape is on the cusp of a transformative shift, influenced by several converging trends. These promise to reshape how over 8 billion individuals and 300 million businesses access and interact with financial ecosystems. These trends present both opportunities and challenges, requiring nuanced, forward-thinking policy and technological frameworks to harness their potential. Throughout history, the convergence of underlying technologies and trends, like the industrial revolution's combination of mechanisation, steam power and mass production, or the digital age's blend of the internet, GPS and smartphones, has created new innovation playgrounds. This led to seismic shifts in human society and economic structures. We believe that we stand on the threshold of a similar opportunity in financial services. This is driven by:

Increasing economic aspirations and participation of individuals and businesses: The rise of the digital age has amplified the economic aspirations and capabilities of individuals and businesses. It has also heightened expectations for more accessible, personalised, affordable and efficient financial services. The surge in formalisation of informal activities, entrepreneurial ventures and market participation reflects the wide range of financial needs and applications. This expanding landscape of economic activity necessitates a financial system robust enough to support the evolving and diverse needs of an interconnected, digitally empowered population.

Clear intent from regulatory agencies: There is a clear regulatory intent to harness the potential of financial innovations in a safe and controlled manner. This is reflected in initiatives like open finance, open banking, tokenisation of central bank money, digital asset regulation, introduction of fast payment systems and many others across multiple jurisdictions. While most of these initiatives start with a broader vision, they often become siloed at the time of implementation. Therefore, there is a need for an architecture that supports a unified approach. This can ensure that the initial broad vision can be maintained and realised effectively.

Universal access: The proliferation of smartphones and the expansion of internet access are pivotal in democratising access to financial services, enabling digital applications and allowing user-centric experiences for a wider demographic. While smartphones and internet connectivity will drive the adoption of digital-first solutions, applications in the Finternet would be accessible through various means, including feature phones and assisted modes, ensuring no individual is left behind.

Advances in cryptographic technology: Recent progress in cryptographic methods and technologies has significantly enhanced the capabilities of financial systems, offering features like programmability, immutability, composability, interoperability and verifiability. When leveraged well, these technological advances enable more secure, efficient and seamless interactions across different financial platforms and systems.

Advances in computing and artificial intelligence (AI): AI is set to revolutionise financial services, enhancing identity verification, fraud management, underwriting and advisory services. Advances in cloud computing and other computational technologies have enabled the development of sophisticated AI tools. These technologies, including voice-based interfaces and multilingual experiences, are breaking down traditional barriers, making financial services accessible to a wider audience, including people with disabilities or non-native language speakers, and ensuring inclusiveness in the financial ecosystem. The emergence of large language models and other forms of generative AI is a significant technological advance, with cloud infrastructure playing a crucial role in processing and analysing vast data volumes. This evolution in AI can transform financial systems, particularly in fraud detection, where AI models can quickly identify and respond to suspicious activities, enhancing security. Generative AI can streamline many back office tasks, lowering costs and reducing processing times in activities like document scanning, transcription, data entry, customer request screening and text summarisation. Additionally, AI's ability to detect novel data patterns helps financial institutions better understand customer needs and creditworthiness. It also streamlines compliance processes, such as know-your-customer checks, reducing costs and improving speed and accuracy.

2. A vision for a more technologically advanced financial system

Financial systems lie at the core of modern market economies. They are the venue where individuals and businesses save, borrow, invest and insure themselves. When operating efficiently and affordably, financial systems fulfil two primary objectives. First, they provide a means for individuals to safeguard their financial well-being. Second, they channel financial resources into generating economic activity, which is vital for spurring new ideas and innovations. Well-functioning financial systems help to foster growth and development, in doing so benefiting all members of society. In contrast, poorly functioning financial systems harm a country's economic performance and, more importantly, the well-being of its citizens.

It follows that improving the functioning of the financial system is an important public policy objective. Technological advances could bring the financial system closer to people and businesses at lower cost and with greater efficiency. But technology alone is not enough. It needs to be combined with an efficient economic and financial architecture and robust governance and regulatory arrangements. To assemble all three components, a coherent vision of what the financial system should deliver is essential.

In this section, we first describe what we see as the key shortcomings of today's financial system. We then explain how technology could help to overcome many of these shortcomings. Finally, we present a vision of the future financial system.

2.1 Shortcomings of the current financial system

In many respects, today's financial system is still serving the past, not the future. It has numerous shortcomings. Many fall within three broad categories: speed, cost and reduced availability.

Speed: the financial system is too slow

The vast increases in the speed of information flows and communications that have transformed many aspects of everyday life have not left a commensurate imprint on the financial system. Admittedly, there have been improvements in retail payments, with the introduction of fast payment systems being notable examples (Aurazo et al (2024), Bech et al (2020), Frost et al (2024)). But these are the exception. Many financial asset transactions, such as those involving shares, bonds or real estate, still take days to settle and, for many individuals, are difficult, if not impossible, to access.

Antiquated clearing, messaging and settlement systems are a significant source of delays. Even when individuals use sophisticated front-end interfaces to make supposedly "digital" transactions, behind the scenes, movements of money and other financial assets often rely on the owners of siloed proprietary databases to initiate and process transfers. These databases often operate with different technical standards and governance arrangements, connected through third-party messaging systems that may not interact smoothly with each other.³ In some cases, the exchange of physical contracts is still required. Particularly in cross-border transactions, differences in time zones and business hours can slow the process further.

Compliance with regulatory requirements, such as those related to anti-money laundering and combating the financing of terrorism (AML/CFT) rules, are another source of delay. The regulations themselves are, of course, critical to deter illicit activity and preserve the integrity and stability of the financial system. But their implementation is often manual, bespoke and inefficient. For example, the same verification of customer identity may be repeated several times in a single transaction. The resulting inefficiencies can fall as heavily upon individuals and businesses making legitimate transactions as they do

³ Some efforts to harmonise messaging standards are currently under way, with the G20 cross-border payments programme initiative to promote the global adoption of the ISO 20022 message standard being a leading example.

on those making illicit ones. These compliance costs have been increasing rapidly due to the greater sophistication of criminal threats to the system and rising regulatory expectations.

Costs: the financial system is too costly

Slow transactions are costly ones. Particularly in EMDEs, delays between the execution of trades and their settlement tie up working capital, forcing businesses to hold large cash reserves or rely on expensive forms of borrowing like credit cards to tide themselves over. For individuals, long waits for wages and government transfers to appear in their bank accounts may leave them with no alternative but to seek out short-term loans, often at high interest rates. Settlement delays also create so-called “counterparty risk”, ie the risk that one or more participants will not provide the money or financial assets to deliver on their side of the transaction. To mitigate these risks, participants in financial transactions are often required to post collateral, which comes with its own associated financial costs.

Manual processes can also lead to errors. Reliance on external verification and messaging systems means that participants in financial transactions often have an incomplete view of the actions of other parties and cannot track the progress of their payments in real time. Extensive auditing, compliance and other back office costs are required to monitor the progress of payments and other financial transactions and confirm their progress. Errors or inconsistencies in messages between financial institutions may go undetected and then take time to resolve. This too imposes costs on users of financial services.

Lack of competition is another source of costs. Some of these costs are explicit, in the form of high prices or fees for services. Such costs can be particularly large for individuals and firms making low-value transactions or cross-border payments. The cost of sending cross-border remittances, for example, averages 6.3% of the total cost of the payment (FSB (2023), World Bank (2023)). Other costs are less visible, such as poor service quality or the handicapping of innovation.

Access and availability: the range of financial services and products is too limited

The combination of slow systems, high costs and a lack of competition ultimately limits the range of financial services on offer. High costs, for example, can make certain financial services uneconomical in some locations, especially rural and low-income areas. The contraction of cross-border correspondent banking networks in recent decades is a prime example. Absence of choice leads individuals to make sub-optimal decisions, such as maintaining large balances in cash accounts at low interest rates or, as noted above, relying on expensive forms of credit, like credit cards, for borrowing.

In many cases, a combination of challenging geography and old technology also hinders access to financial services. In some EMDEs with relatively poor transportation connections, even basic financial services, like the provision of physical notes and coins, may be lacking (Jahan et al (2019)). The deployment of digital financial services as a complement to existing ones, accessible through mobile phones and other electronic devices, offers the prospect of overcoming many of these geographical challenges. But in many jurisdictions these are still limited to a relatively basic set of financial assets and services.

There are also immense hidden costs in terms of potentially worthwhile transactions and products that never materialise. To name just one example, trade finance procedures – which can lead to significant delays between the time when businesses produce goods and services and the time when they receive payment – could be significantly streamlined through the use of smart contracts to enable conditional, or partial payment.⁴ However, such contracts are difficult, if not impossible, to implement in today’s financial system. This represents a significant deadweight loss of economic opportunity. As a result, markets are unnecessarily incomplete. And incomplete markets are not conducive to higher welfare.

In the extreme, individuals may be unable to access financial services at all. Despite considerable progress in recent decades, 1.4 billion adults are still excluded from the financial system (Demirgüç-Kunt et al (2022)). And even if they have some access, the extent of financial system participation is often limited.

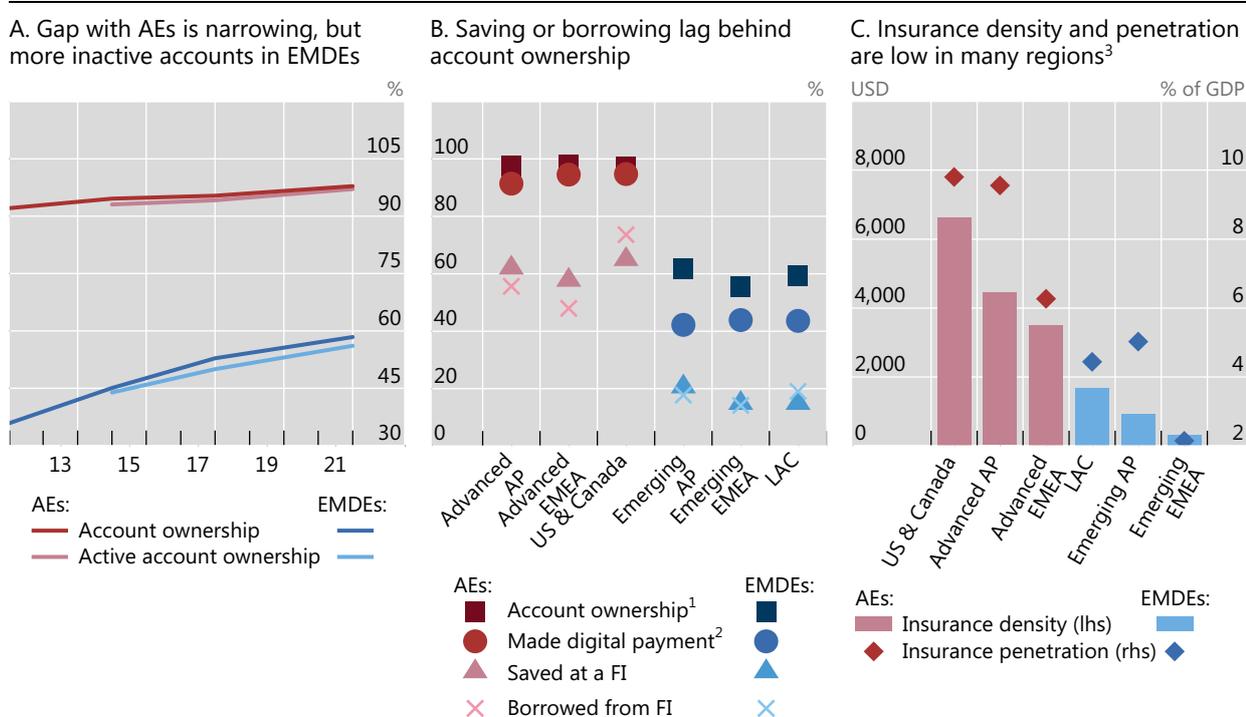
⁴ See BIS (2023) for a more detailed explanation of the use of smart contracts in trade finance.

According to the World Bank’s Findex database, while 76% of adults had a transaction account, only 55% owned a debit or credit card and 59% made a digital payment in 2021. Access to credit and savings is even more constrained, with only 28% of adults borrowing from a formal financial institution and 29% saving money in the financial system.

Lack of access to financial services is particularly acute in EMDEs (Graph 1.A). Only a quarter of adults in these jurisdictions use a savings account, and about half borrow – with more than half of this coming from informal sources (Demirgüç-Kunt et al (2022)). Access to credit or savings products is even lower in some regions, such as Latin America and the Caribbean (Graph 1.B), and among certain demographic groups such as those defined by age, gender or education.⁵ Meanwhile, small businesses in EMDEs often have insufficient credit for working capital. Lack of retail access to investment and insurance constrains households from accumulating wealth or building resilience. In most EMDEs, insurance premiums per capita (“insurance density”) are less than \$1,000 per year; premiums relative to GDP (“insurance penetration”) are less than half the level in advanced economies (AEs) (Graph 1.C).

Access to financial services has improved, but gaps remain

Graph 1



¹ The graph shows the percentage of adults who hold a financial institution or mobile money account. ² The graph shows the percentage of adults who hold a financial institution (FI) or mobile money account, who made a digital or debit card payment and saved or borrowed via financial institution. ³ Insurance density is defined as premium per capita in 2022. Insurance penetration is defined as premium as a percentage of GDP in 2022. Includes life and non-life premiums (including health).

Sources: World Bank Global Financial Inclusion (Global Findex) Database; Swiss Re Institute; BIS.

The inability to access financial services lowers welfare. Measures of financial health – defined as the extent to which a person or family can successfully manage their financial obligations and have confidence in their financial future – are much lower in EMDEs than in AEs (Graph 2.A; Cantú et al (2024)). Limited access to financial services hinders individuals' ability to manage risks and save for the future (Dupas et al (2013)). It also impairs small businesses' ability to invest in productive activities, thus stifling

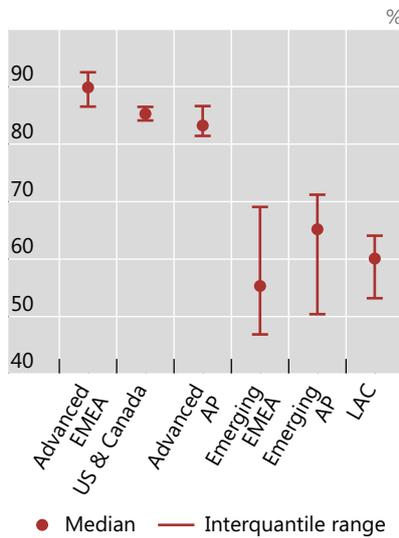
⁵ For example, fewer young people aged between 14 and 25 have access to a loan from a financial institution (17%, compared with 32% of people aged over 25). People with secondary or higher education often have more access than those with less education (38% vs 18%). Women and men have similar access to credit (28% vs 31%).

growth and development (Banerjee and Duflo (2014)). Ultimately, access to credit and financial services is instrumental in empowering individuals to escape poverty by investing in human capital and other income-generating activities and enhancing overall economic inclusion.

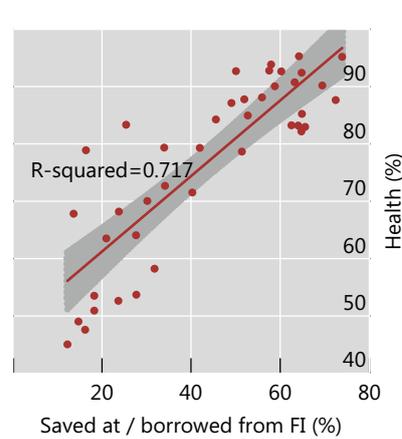
The link between financial inclusion and financial health

Graph 2

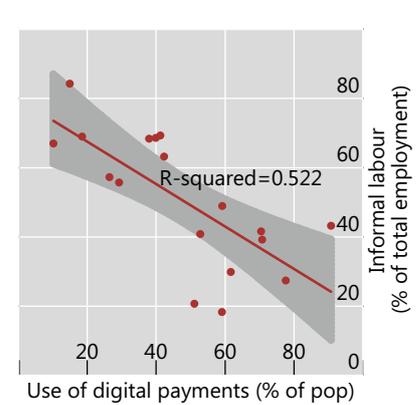
A. Measures of financial health are poorer in EMDEs¹



B. Greater use of financial services translates into better financial health²



C. Digital payments are associated with less informality²



¹ Financial health is estimated as one minus the average fraction of survey respondents that are very worried about medical expenses, saving for old age, paying bills and affording education or rely on family and friends for funds in case of an emergency. ² Each dot represents a country in 2021. The x-axis indicates the average fraction of survey respondents that save or borrow in a financial institution. The y-axis is one minus the average fraction of survey respondents that are very worried about medical expenses, saving for old age, paying bills and affording education or rely on family and friends for funds in case of an emergency.

Sources: Aguilar et al (2024); World Bank Global Financial Inclusion (Global Findex) Database; BIS.

2.2 Technology-driven opportunities

Recent technological innovations have the potential to overcome many shortcomings of today's financial system.

Some progress has already been made. In many jurisdictions, smartphones have facilitated payments and lowered transaction costs. Digital identity systems have made it easier and cheaper to open bank accounts (D'Silva et al (2019)). The use of alternative data, such as those generated by quick response (QR) payments and fast payments, has underpinned digital credit. This has benefited individuals and small businesses (Beck et al (2022)) and broadened access to credit by substituting for collateral (Gambacorta et al (2022), Aurazo and Franco (2024)). Meanwhile, novel retail investment and insurance platforms have created new pathways to help individuals build wealth and diversify risks. In some countries, fast payment systems have emerged as a key innovation. The remarkably fast adoption of these systems holds lessons for other novel financial technologies (see Box B).

The benefits of such innovations are clear. In aggregate, there is a positive correlation between use of borrowing and savings products and measures of financial health (Graph 2.B). Greater use of digital payments is associated with less economic informality, ie a smaller share of the "shadow economy" (Graph 2.C). This may reflect the use of digital payments to merchants, and digital payments for payroll, in creating a data trail that helps to formalise previously unrecorded (cash-based) activities (Aguilar et al (2024)).

Fast payment systems: lessons for digital public infrastructure

Fast payment system (FPS) are now available to households and businesses in around 119 jurisdictions; in others, authorities plan to implement an FPS in the coming years. The success of FPS in terms of adoption and usage varies across jurisdictions, as does the role of central banks, which can be a catalyst, overseer or operator.

Recent experiences suggest that certain design features of FPS are particularly important to spur user uptake (Frost et al (2024)). Thailand's PromptPay, India's Unified Payments Interface (UPI) and Brazil's Pix are three examples that stand out as they have achieved remarkable success in driving the adoption of digital payments (Graph B1.A), They have also facilitated private sector innovation and the entry of new payment service providers (PSPs) (Graphs B1.B and B1.C). These FPS share a number of features: (i) a user-centric design, with a number of use cases; (ii) a robust infrastructure for settlement; (iii) a rulebook for participation, eg mandatory participation of large banks; and (iv) a framework for governance that includes a strong role for the public sector, in particular the central bank. In addition, these FPS include open application programming interfaces (APIs) and aliases (eg mobile phone numbers) to initiate transactions, and low transaction costs.

Notably, both UPI and Pix allowed room for private sector (non-bank) participation. In fact, UPI payments (developed by the Reserve Bank of India and the National Payments Corporation of India) only took off when third-party application providers (now dominant) were allowed to connect in 2018. The private sector played a crucial role in bringing UPI to the financially excluded, through innovations such as all-in-one quick response (QR) codes and audio-based payment confirmation, targeted at small merchants in areas with poor internet connectivity. Pix has also encouraged private sector innovation by adopting standardised APIs specified by the Central Bank of Brazil, which enabled merchants to integrate Pix payments into their online shopping experience through QR codes. Additionally, innovators leveraged Pix QR codes to pay for tolls and gain access to private buildings.

These examples highlight the importance of having both regulatory oversight and private sector participation in achieving public policy goals.

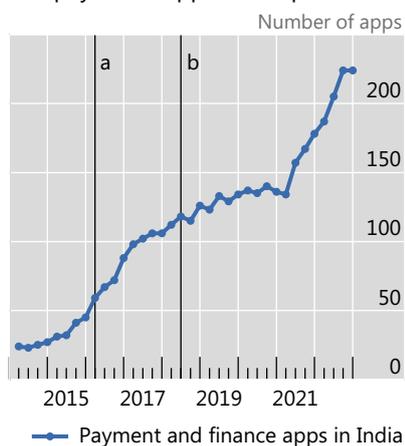
Fast payment systems in India and Brazil

Graph B1

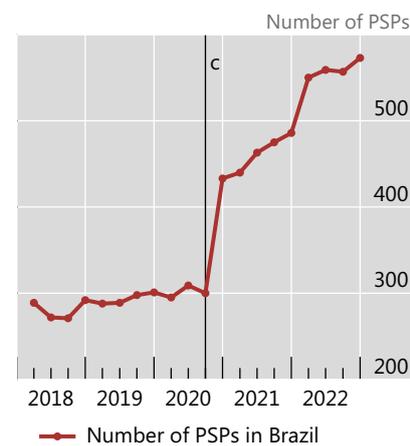
A. Transactions per capita show wide UPI and Pix adoption¹



B. The launch of UPI has spurred a rich payments app landscape



C. Introduction of Pix has gone hand in hand with more PSPs



^a Introduction of UPI 1.0. ^b Introduction of UPI 2.0. ^c Introduction of Pix.

¹ Monthly data.

Sources: Central Bank of Brazil; World Bank; National Payments Corporation of India; Sensor Tower; BIS.

Successful though these innovations have been, their widespread use is still restricted to a small – though growing – number of jurisdictions. Further gains from broader adoption of these technologies are

still possible. Meanwhile, other technological innovations that have yet to enter the mainstream offer the prospect of further progress.

Tokenisation is a leading example. Tokenisation involves generating a digital representation of financial or real assets that reside on a programmable platform (Aldasoro et al (2023)). Traditionally, financial systems have separated databases – which record claims on financial assets (eg a land title registry, or a bank’s record of customer deposits) – from the governance rules and applications that allow users to transact these assets (eg an e-banking app). Tokenisation removes the distinction between the two as all the information required for the transaction of a financial asset (eg ownership, rules and logic governing transfers) resides in one place. This greatly simplifies the mechanism for trading assets, while also enabling more complex pre-programmed and contingent asset transfers, which would not be feasible in a non-tokenised environment.

Adoption of tokenised financial assets could ease many of the bottlenecks that exist in the current financial system. Tokenisation fundamentally reshapes the process of financial transactions. Instead of long, complex sequences of messages passed back and forth between financial institutions, the tokens themselves trade, along with all of the ownership, value and regulatory information that would typically be recorded in databases.

While tokenisation does not eliminate the role of intermediaries, it changes the nature of that role. Intuitively, intermediaries in a tokenised environment primarily serve a governance role, as the curator of the rules governing the transfer of tokens, rather than as a bookkeeper which records individual transactions on behalf of account holders. By reducing the dependency on the clearing and messaging systems, tokenised assets allow for atomic settlement – that is the synchronous and simultaneous settlement of multiple legs of a single financial transaction – thereby reducing counterparty risk and lessening collateral requirements. Programmability could also make viable some contingent financial transactions, which are infeasible in today’s financial system. Tokenisation also provides greater scope for composability, whereby several transactions are bundled into a single executable package. Features such as these open the door to the development of entirely new financial products to help individuals and businesses save, invest and insure themselves. In sum, tokenised financial assets would offer individuals and businesses faster service, lower costs and greater choice than their traditional alternatives.

The emergence of large language models and other forms of generative artificial intelligence (AI) is another technological advance that could materially influence the financial system. Application of AI models could deliver a step change in the volume and types of data that financial institutions can process. Generative AI, in particular, could streamline many back office tasks, lowering costs and processing times. For example, scanning, transcribing or verifying documents, data entry, screening customer requests or summarising texts can all be done more effectively when supported by AI. AI models can locate previously unidentified data patterns, helping financial institutions to predict the financial needs, or borrowing ability, of their customers more accurately. Moreover, AI models could also help financial institutions automate compliance procedures, such as know-your-customer (KYC) checks, greatly reducing their cost while increasing their speed.

But technology is not an end in itself. The benefits of tokenised assets, and other forms of financial innovation, are limited so long as the assets exist in isolation. For example, trading a tokenised asset in exchange for a non-tokenised counterpart would still require a sequence of messages to link the tokenised and non-tokenised systems. Clearing and settlement could still be subject to lengthy delays and points of failure. And, if the legal and regulatory framework governing tokenised assets is undeveloped, such a trade may not even be possible. To unlock the full benefits of tokenisation, it is necessary to bring multiple tokenised assets together on common platforms, with the backing of a robust governance and regulatory framework. This, however, is a more ambitious project than simply offering existing financial assets or services in a more technologically advanced form. Hence, in order to proceed it is necessary to first identify the tangible objectives one wants to achieve. That is, one needs to pursue a vision for the future financial system. We next turn to this vision.

2.3 The Finternet: a vision for the future financial system

We introduce the concept of the Finternet as a vision for the future financial system. This vision entails a network of interoperable financial ecosystems, with individuals and businesses positioned at the centre of their financial interactions. The system rests on three foundational pillars. These are: (i) an economically sound architecture; (ii) the integration of advanced technologies; and (iii) a robust regulatory and governance structure.

The design of the economic architecture should put its users at the centre. Individuals and businesses should have the greatest possible control over the financial transactions they make, and the time and way in which they make them. Financial services should be cheap, secure, reliable and easily accessible.

To fulfil this vision, the financial system will need to make full use of innovative technology to enhance user experiences. At the same time, it cannot rely on specific technological platforms, architectures or data standards. Technology will continue to advance, and so the financial system needs to remain adaptable to technological progress. And within that flexibility it should empower users to interact with financial services through a range of devices and interfaces. The paper proposes an approach that integrates essential technological features such as interoperability, verifiability, programmability, modularity, scalability, security and data empowerment.⁶ The adoption of the system can occur in stages, allowing different participants to integrate and go live at their own pace. This phased approach accommodates the varying readiness and capacities of entities within the ecosystem, ensuring a smooth transition to the new financial framework.

Promoting user choice also means dismantling the barriers and silos that exist in the current financial system. Instead of sluggish clearing and messaging systems, minimum transaction values, manual processes and delayed settlement, individuals should have control over what financial assets they trade, in what amount and at what time.

An open and efficient financial system should foster robust competition, encouraging new entrants and keeping existing service providers nimble. This will promote continuous innovation within the financial industry and lower costs for consumers. To allow users to take full advantage of this competitive playing field, it will be necessary to ensure that individuals have control over their financial data, including by supporting multiple verifiable identities to enable enhanced privacy while maintaining accountability.

Not everything should change. Many of the key underpinnings of today's financial system, such as the two-tier structure with a clear role for the public and private sector, should remain in place. Central bank money should still serve as the trusted foundation of the financial system, with settlement in wholesale central bank money on the central bank's balance sheet being the determinant of finality in financial transactions. Commercial banks should retain a key role as intermediaries between savers and investors and as providers of commercial bank money. But even in these cases, the assets that these institutions offer to the public should take on more advanced technological representations, in the form of wholesale tokenised central bank money and tokenised commercial bank deposits.⁷

Robust governance will remain essential. To maintain trust in the security and integrity of the financial system, all participants should comply fully with all regulatory and legal obligations. This includes measures to safeguard individual privacy and business confidentiality. Here, too, the application of technology will be a critical enabler of security, speed and efficiency.

Public authorities will play an important role in the future financial system. Through the development of digital public infrastructure, they can establish the platforms, rulebooks and regulatory

⁶ See also Nilekani et al (2024).

⁷ That said, traditional financial assets, including notes and coins, should continue to be available for individuals and businesses who wish to use them.

protections required to deliver an open and efficient financial system (see Box C for lessons from digital public infrastructure in India). And, as suppliers of central bank money, they will continue to provide the foundational asset for the entire monetary and financial system. With this infrastructure and regulatory base in place, private institutions will have freedom to compete and innovate to deliver better, faster and cheaper services to their customers.

Box C

Lessons from digital public infrastructure in India

The implementation of digital public infrastructure (DPI) illustrates the profound impact that interoperability, a unified approach, universality, evolvability, user-centricity and modularity can have on the financial ecosystem. As recognised by the Global Partnership for Financial Inclusion under the G20, DPIs are instrumental in enhancing the access, usage and quality of financial services, thus driving innovation and competition. This box provides a brief review of examples from India (see also Alonso et al (2023), Ardic Alper et al (2019), D'Silva et al (2019) and Tiwari et al (2022)).

Aadhaar: It exemplifies universality and user-centricity through its biometric-based, verifiable identity mechanism issued to over 1.3 billion individuals. By facilitating a presence-less customer onboarding process, Aadhaar has reduced transaction costs from \$15 to \$0.07, thereby extending banking and dematerialised account access across all segments of society. This infrastructure has significantly accelerated financial inclusion, enabled bank accounts for all, and bridged traditional gender and age disparities in financial participation within a mere nine years – a task that would have otherwise spanned several decades.

Unified Payments Interface (UPI): As a hallmark of interoperability and a unified system built by the Reserve Bank of India and the National Payments Corporation of India, UPI has revolutionised digital payments, enabling comprehensive transaction modalities across peer-to-peer, peer-to-merchant and government-to-person payments (see also Box A). UPI's facilitation of 117.6 billion transactions (\$2.2 trillion) in 2023 underscores the scalability of the digital payment system and the pivotal role of digital payment infrastructures in democratising financial services and fostering inclusion. Leveraging Aadhaar and digital payments, India's direct benefit transfers (DBT) have not only optimised welfare scheme deliveries but also effected substantial fiscal savings by curtailing leakages in excess of \$30 billion.

Account Aggregators (AA): The AA system champions user-centricity and modularity, granting individuals and entities sovereign control over their financial data. This enables individuals to use their data as "digital capital" for accessing financial services. The facilitation of over \$2.4 billion in loans since its launch signals the potential of consent-based, machine-readable data in broadening financial inclusion and reducing fraud. It is an example of how multiple financial regulators (the Reserve Bank of India, the Securities and Exchange Board of India, Insurance Regulatory and Development Authority of India, the Pension Fund Regulatory and Development Authority, and India's Ministry of Finance) and market players (through the Sahamati Foundation) came together to enable an interoperable and unified ecosystem across diverse sectors for the user.

Open Networks: The implementation of Open Transaction Networks (OTNs) for commerce, mobility and other sectors particularly through the Open Network for Digital Commerce (ONDC), exemplifies the lowering of transaction costs and barriers to entry, thereby cultivating an environment ripe for innovation, competition and market expansion. The ONDC, underpinned by the Beckn protocol, is pioneering a significant shift in the transaction economy, demonstrating how open, protocol-based systems can fundamentally alter market dynamics and foster inclusive growth.

In sum, these DPI components collectively underscore the benefits that can be realised through the strategic application of the foundational digital principles we highlight in this paper. For policymakers, these examples offer compelling evidence of the dramatic and far-reaching success that can be achieved in financial inclusion and the broader economic landscape through the thoughtful implementation of digital infrastructure.

3. From vision to reality

How can we transform the vision for the Finternet into reality? In this section we outline a promising vehicle to take us there: a token-based financial system, supported by unified ledgers. We first describe the concept, its economic and financial rationale and basic technological architecture. Following this high-level overview of the concept, we lay out the nuts and bolts of how the architecture of the Finternet could look in practice. Finally, we discuss the regulatory, legal and governance questions that authorities will need to address for unified ledgers, and the Finternet more broadly, to function effectively in a real-world setting.

3.1 Unified ledgers as a vehicle for an improved financial system

Unified ledgers provide a “common venue” (ie a shared programmable platform) where digital forms of money and other financial assets co-exist. They aim to provide a quantum leap over existing financial infrastructure by seamlessly integrating transactions and opening the door to entirely new types of economic arrangements.

The concept of unified ledgers does not mean “one ledger to rule them all” – a single ledger that encompasses all financial assets and transactions in an economy. Depending on the needs of each jurisdiction, multiple ledgers could coexist. Application programming interfaces (APIs) could connect these ledgers to each other and other parts of the financial system that exist outside the Finternet. The functions of individual ledgers could evolve over time, and ledgers might even merge as overlaps in scope expanded. The role of unified ledgers could also vary by jurisdiction. In economies where individuals already have access to a broad range of reasonably efficient and competitive retail financial services, the main role of unified ledgers might initially be to enhance the efficiency of wholesale financial services.⁸ In jurisdictions with lower levels of financial inclusion, in particular in many EMDEs, unified ledgers might have a stronger retail focus.

Unified ledgers have two defining characteristics. The first is that they combine all the components needed to complete financial transactions – financial assets, ownership records, rules governing their use and other relevant information – in a single venue. The second is that money and other financial assets exist on the ledgers as executable objects. This means that they can be transferred electronically using pre-programmed “smart contracts”. Together, these design features allow individuals and businesses to move money and other assets safely and securely, with less need for external authentication and verification processes or reliance on external clearing, messaging or settlement systems.

The structure of the Finternet can be described in terms of a series of building blocks (Graph 4). The unified ledgers themselves would contain digital representations of central and commercial bank money and other tokenised financial assets. Within a given ledger, different types of assets would reside in separate partitions that would be owned and operated by their respective operating entities, which we refer to as token managers. The ledgers would also include the information necessary for their operation, such as the data required to ensure the secure and legal transfer of money and assets (eg digital identity and laws, regulations and rules governing transactions) as well as real-world information sourced from outside the ledger. Meanwhile, a diverse ecosystem of trust and value service providers would help verify the identity and preserve the security of users of the system and their financial assets.

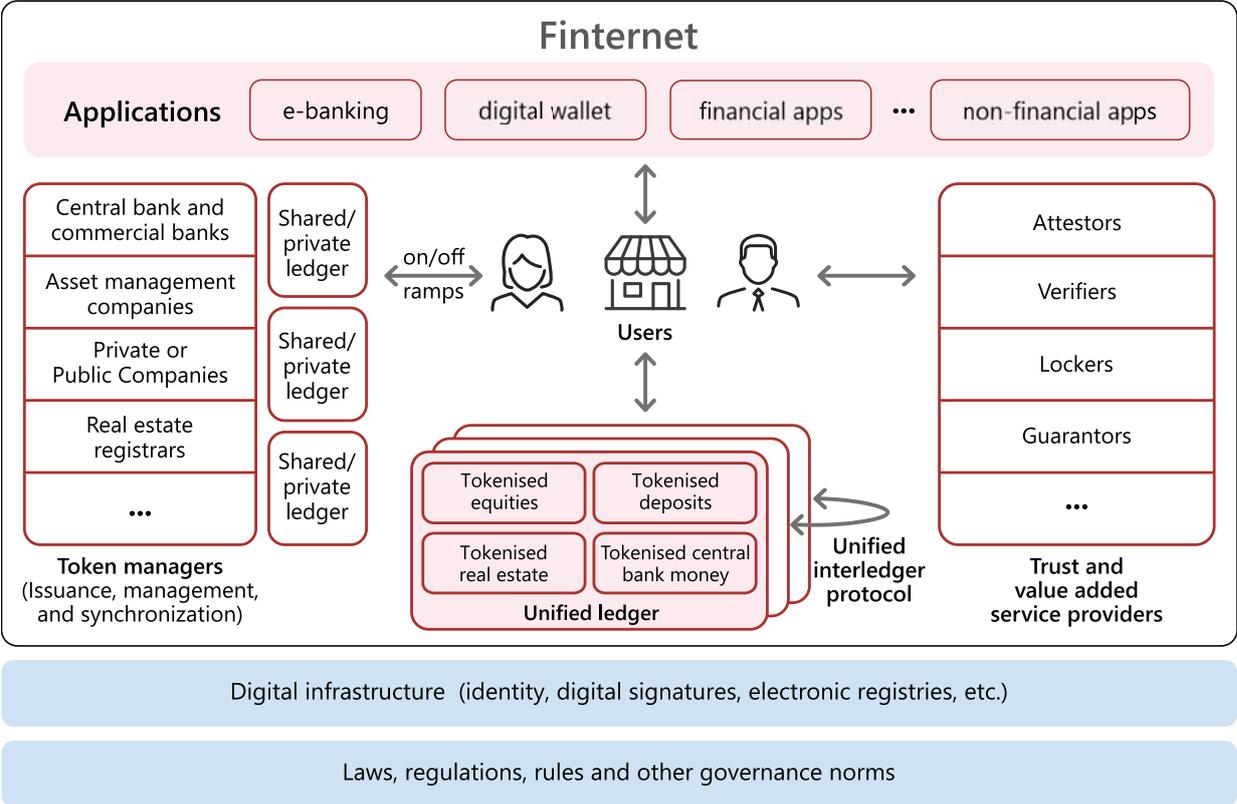
Individuals and businesses would interact with the ledgers through applications. These could exist in multiple forms and allow users to conduct transactions within individual ledgers, between ledgers or in exchange for assets that exist outside the Finternet. For example, an individual’s e-banking app might

⁸ A wholesale-focused unified ledger could still deliver significant benefits to end users through lower costs, greater reliability and faster transaction settlement.

record their tokenised deposits that reside on a unified ledger alongside their non-tokenised deposits that exist in a traditional database. The apps would allow users to execute transactions directly, or through smart contracts, enabling a far greater degree of flexibility and customisability than is available in today's financial system.

The high-level architecture of the Finternet

Graph 4



Source: Authors' elaboration.

While unified ledgers could in principle contain any financial asset, tokenised money is a core requirement. Money provides the basic unit of account to denominate transactions. And, as the means of payment, it represents one side of almost all financial transactions.

As in today's financial system, the monetary system in the unified ledger system would have two tiers. Central bank money would represent the first tier and commercial bank money the second.

Settlement of commercial banks' accounts on the central bank's balance sheet is the ultimate guarantee of finality of any financial transaction. As such, wholesale central bank money is a necessary foundation for any unified ledger. Tokenised wholesale central bank money would play a similar role to reserves in today's financial system, but offer the enhanced functionalities afforded by tokenisation. Some central banks might also choose to issue tokenised central bank money in retail form – a digital equivalent of today's banknotes – to provide additional choice for users.

Commercial bank money would exist on unified ledgers in the form of tokenised deposits.⁹ These assets would provide the natural retail complement to wholesale tokenised central bank money. As in

⁹ Unlike so-called stablecoins, tokenised deposits would not be bearer instruments. Instead, they would trade using a "burn-issue" model (Garratt and Shin (2023)). Asset transfers are accomplished by deleting ("burning") tokenised deposits at the payer's bank and assigning ("issuing") new tokens at the payee's bank. The deletion and creation of private money tokens has an associated movement of tokenised wholesale central bank money.

today's financial system, commercial bank money would serve as the primary means of payment for most individuals and businesses. And it would be supported with the same institutional arrangements, including regulation, supervision, deposit insurance and settlement on the central bank balance sheet that exists today, thereby ensuring the singleness of money.¹⁰

Besides central and commercial bank money, unified ledgers could in principle contain an almost infinite variety of other financial and non-financial assets. All that is required is that the assets exist in tokenised form. Tokenising assets involves costs as well as benefits. One can view candidates for tokenisation as lying on a continuum (Graph 5; Aldasoro et al (2023)). At one end are assets in systems that require frequent manual workflow procedures and have complex legal and regulatory frameworks. Residential real estate could be one example. Tokenising these assets would involve multiple challenges, although the potential gains from doing so successfully would be significant. At the other end are financial assets in digital, mostly automated systems with streamlined processes and clear legal and regulatory frameworks. Government bonds, at least in AEs, are an example of this type of asset. While these assets would be the least costly to tokenise, they might deliver smaller benefits than some others as their transactions are already relatively fast, cheap and convenient.¹¹ The mix of assets that exist on unified ledgers is likely to evolve over time. It could also vary across jurisdictions, depending on their specific needs as well as their institutional and legal arrangements.

The tokenisation continuum

Graph 5

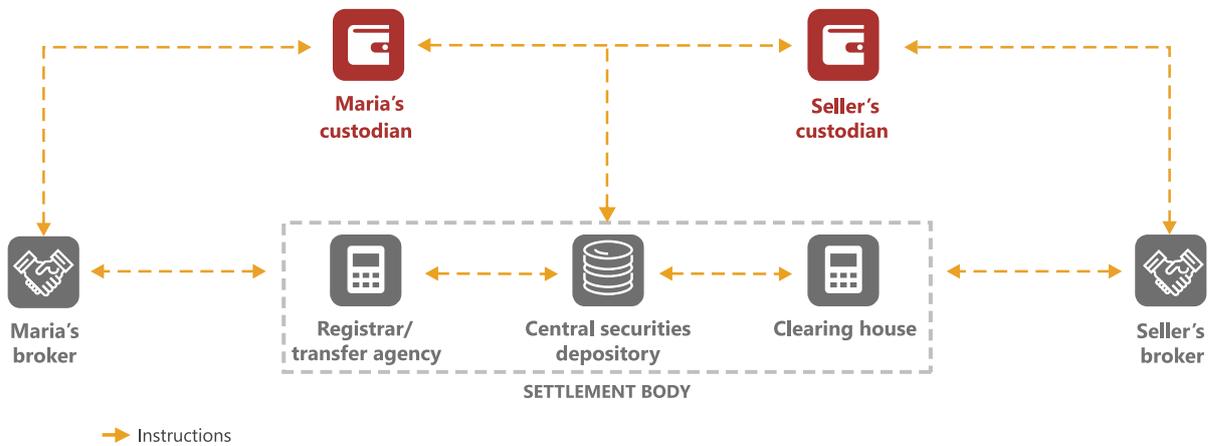


Source: Aldasoro et al (2023).

To understand the transformational possibilities of unified ledgers, consider a simple financial transaction: Maria's decision to purchase a security (eg a share in a company). In today's financial system, this seemingly basic transaction would require a complex series of messages between multiple parties (Graph 6). Maria would start the process by contacting her broker. The broker, in turn, would buy the shares or direct the trade through a market maker. At this point, several other parties may be involved to execute and settle the transaction. For example, a central securities depository will be responsible for electronically managing the securities. They, in turn, must verify the identity of the participants in the transaction and ensure reconciliation and confirmation of what is being settled with the relevant third parties (eg clearing agents). An equivalent process will also occur for the seller of the securities on the other side of the transaction. This "settlement cycle" could take several days, with the lengthy messaging chains creating multiple points of failure.

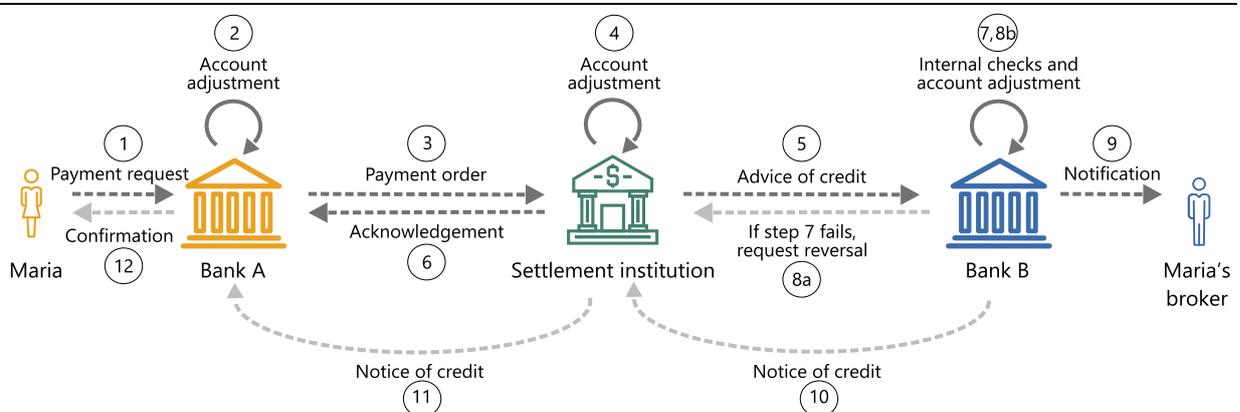
¹⁰ The singleness of money refers to the fact that deposits held at different commercial banks and central bank money all trade at par, that is, one dollar (or franc, peso or rupee) deposited at one bank is worth one dollar deposited in another bank. See Carstens (2023) for a deeper discussion of this issue.

¹¹ That said, the tokenisation of government bonds could facilitate greater access to these financial assets by retail investors.



Source: BIS (2023).

Moreover, the transfer of the security is only one part of the transaction. The other part would involve the banking system (Graph 7). As part of the share transaction, Maria would send a payment request to her bank, referred to here as Bank A (step 1). The bank would respond by debiting Maria's account by the transfer amount together with any fees (step 2) and sending a payment order to the settlement system (step 3). The settlement system debits Bank A's settlement account and credits the account of Maria's broker, Bank B (step 4). It then sends an advice of credit with a reference number to Bank B (step 5). This follows an acknowledgement with a reference number to Bank A (step 6). Bank B must ensure that Maria's broker has an account and perform any KYC or AML/CFT checks (step 7). If any of these checks fail, then Bank B will need to send a reversal request to the settlement institution (step 8a). Otherwise, Bank B credits Maria's broker's account (step 8b) and sends a message confirming the account adjustment (step 9). In some systems, additional approvals and confirmation messages are necessary (steps 9 and 10). If Maria and her broker had been residents of different countries, multiple correspondent banks would have been involved. Each message would take time, creating a lag between the execution of the transaction and its settlement. A single failure at any point on the chain would be enough to stop the transaction from completing. In fact, any actions already taken would have to be undone, a costly process that involves manual actions.

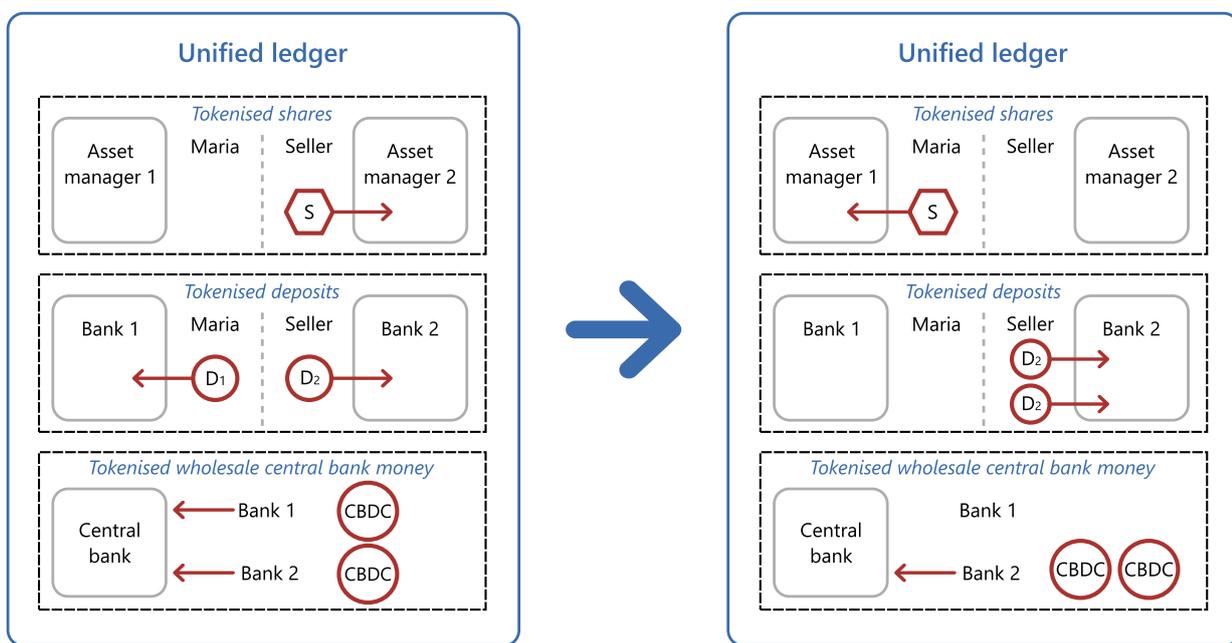


Source: BIS (2023).

Now consider instead how the transaction could work on a unified ledger. All of the assets involved in the transaction – the securities being traded, Maria and her broker’s bank accounts and the banks’ reserves held at the central bank – could in principle exist on the same ledger. Moreover, the assets would be tokenised and hence be programmable. All information that would ordinarily be stored in financial institutions’ databases is contained within the tokens and may be modified through smart contracts. The execution of the transaction would prompt a synchronous movement of the share tokens into Maria’s digital wallet, a change in the amount of tokenised deposits in Maria’s accounts and a transfer of wholesale central bank money from Maria’s bank to those of the individual who sold her the securities (Graph 8). If all of the assets exist on the same ledger and are governed by a common set of governance arrangements and security protocols, the need for messaging flows would be vastly reduced and the execution, clearing and settlement of the transaction would take place synchronously.

Asset transfers on a unified ledger

Graph 8



Source: BIS (2023).

Essentially, unified ledgers have the potential to resolve many of the pain points in the current financial system.

Financial services would be faster, more secure and more transparent. With less reliance on external verification and messaging, delays between the execution of a transaction (when a user agrees to buy or sell a financial asset or enter into a financial contract) and its settlement (when the asset transfer actually takes place) could shrink dramatically. Eliminating lengthy messaging chains would also reduce the scope for errors in financial transactions. These could in many cases now be recorded, tracked and transferred on a single platform. And, if errors do occur, they would be easier to identify and correct because unified ledgers would create a single, permanent, tamper-proof historical record of transactions that enhances trust and transparency. Moreover, it would be possible to complete all legs of a financial transaction simultaneously and with conditionality, ie the transaction will only take place if certain conditions have been met.

Regulatory compliance would be simpler. Asset programmability would make it possible to embed adherence to relevant rules and regulations within the tokens and transaction instructions in the

system.¹² In other words, policy would exist as code. Meanwhile, verifiable digital identification and seamless data transfers across a ledger would greatly ease financial institutions' compliance with KYC rules.

At the same time, unified ledgers could also enhance user privacy and user control over data. Crucially, information about users and their transactions could be digitally protected. Subject to user consent, it could be shared with other users or financial service providers only on a strictly "need to know" basis.

As well as improving existing processes, unified ledgers would enable entirely new financial products. Increased efficiency and enhanced verifiability would make viable financial services that today's financial system cannot provide, either because they are too costly or because the information required to provide them is too dispersed. Bringing multiple assets onto shared ledgers would allow them to be combined in novel ways, giving users access to financial services better tailored to their wants and needs. Services would also be more flexible, with the composability of asset tokens making it easier for financial institutions to offer low-value services.

Box D

Use cases of unified ledgers and tokenisation

Many interesting real-world applications involve the tokenisation of assets. These range from financial securities to real assets, such as commodities or real estate (BIS (2023)). This box serves to spark the imagination on how unified ledgers could be used in the real world:

Investment and government bonds: Picture **Aarav**, an individual in India, who discovers that investments, including government bonds, are revolutionised through unified ledgers. This system democratises access to financial assets, allowing Aarav and his family to own fractions of bonds, making it possible to build wealth with limited savings. This significantly broadens the investor base and enhances market liquidity. Project Genesis of the BIS Innovation Hub explores this potential in the context of green bonds.

Access to credit: Now consider **Lee Min-su's** small bakery, a cherished local business in Seoul. Tokenised lending applications could dismantle the financial barriers that have long stood in its way, reducing the costs of loan origination. Loans for her are managed automatically, from payment to collateral management, with alternative data providing better insights into credit risk. This is not a distant dream, but a direction in which Project Dynamo of the BIS Innovation Hub is already headed.

Insurance: Imagine the impact on **Carlos**, a coffee farmer in Brazil, who benefits from transformed insurance through unified ledgers offering parametric microinsurance policies. These policies provide customised protection plans to Carlos and his community, allowing them to cope better with the uncertainties of farming. Dynamic insurance policies use real-time weather data and adapt to changing risk profiles, bringing hope and security.

Cross-border payments: Finally, imagine **Sofia**, a nurse from the Philippines working in the United States. With the advent of tokenised money, Sofia finds peace of mind knowing that her hard-earned money can be sent back home more efficiently, securely and affordably than ever before. The process is seamless, ensuring that her family receives the support they need promptly. Project Agorá of the BIS Innovation Hub is exploring how tokenised commercial bank deposits can enhance the speed, cost and reliability of cross-border money transfers.

The stories of Aarav, Lee Min-su, Carlos and Sofia could be merely the beginning of an era brought forth by unified ledgers and tokenisation. This burgeoning technological landscape promises to herald a future ripe for entrepreneurial innovation. The potential applications are boundless.

¹² See Project Mandala from the BIS Innovation Hub.

Unified ledgers could also bolster financial inclusion, particularly in EMDEs. By lowering costs, they would reduce an important barrier that currently locks many people out of the financial system.¹³ By bringing together multiple assets in one digital location, they would enable individuals and businesses to make use of a broader array of financial services. Financial services would be more accessible – individuals who hold tokenised bank deposits on a unified ledger would find it easier to access alternative savings vehicles. The existence of physical infrastructure, like bank branches, would cease to be such a constraint on access to financial services, because the unified ledger would exist digitally and be accessible in various ways through a range of devices. And because individuals would be better able to control and share their data, the lack of verifiable identity documents or credit history would cease to be such a large constraint on financial access. Box D discusses potential use cases of unified ledgers and highlights ongoing work to making these use cases a reality.

3.2 The nuts and bolts of the Finternet

We now delve into some of the specific design and technological aspects of the Finternet. We first provide an in-depth description of unified ledgers, which would serve as the core of the system. We then discuss the necessary steps to safeguard the security of the system.

User-centric Finternet

Delivering universal access to high-quality financial services is central to our vision. Such access is only possible when we place users – be they individuals or businesses – at the core of financial interactions. The key attributes of such a user-centric system, summarised in Table 1, provide a blueprint for a digital economy that is truly by and for the user.

The Finternet represents all the key components and foundational technologies that collectively constitute the solution of unified ledgers and are brought together in a unified manner for the user. It builds upon existing legal frameworks within countries and internationally, serving as a digital extension of traditional legal frameworks. By aligning with laws and regulations, the Finternet adapts to established principles of permissible actions and consequences of non-compliance, ensuring operations remain compliant with both national and international standards. It leverages existing infrastructure, including identity systems, digital signature certificate systems, connectivity, registrars and registries, and digital public infrastructure, along with any other reusable services available within a jurisdiction.

Given these strong foundations, let us walk through the end-to-end flow of a user navigating this system.

Initiating the journey with user onboarding. Our journey starts with users, both individuals and businesses, who aim to manage their assets with ease and security. Upon entering the Finternet, users can create an account with any unified ledger of their choice. They may also create multiple accounts across multiple unified ledgers. Every account is linked to a globally resolvable virtual address, and these addresses are human-readable. A user may set up multiple such addresses (transient or permanent) depending on their use cases, and if desired on multiple ledgers. Users provide their virtual addresses to others for tokens to be issued into or requested from their accounts. In this ecosystem, users are endowed with unparalleled control over their assets. They have the flexibility to create and manage multiple accounts and sub-accounts, tailor their authentication and authorisation protocols for each account and engage in a wide range of transactions across the Finternet. This level of control and flexibility underscores the user-centric ethos of the Finternet. This ensures that users are not just participants but active architects of their financial journey.

¹³ Some forms of tokenised central bank money are being designed in ways meant to address barriers to financial inclusion in payments (Boakye-Adjei et al (2024)). Importantly, unified ledgers could support inclusion beyond payments – in other areas of financial services such as credit, insurance and savings.

Key characteristics of a user-centric Finternet

Table 1

#	As a user I ...	Examples
1	Could be any natural person or legal person	Individuals and legal persons (eg corporations, governments, non-profits, trusts, partnerships)
2	Could use my electronically verifiable identities and verifiable attestations to participate in the ecosystem	<i>Identities:</i> Passport, national (digital) ID card, driver's licence, birth certificate, social security number/card, bank cards, etc <i>Attestations:</i> Investor accreditation, educational degrees, employment history, professional licences/certifications, health/financial records, criminal background checks, social media, etc
3	Could authenticate myself and authorise transactions on any ledger of my choice	PIN, biometric verification, hardware token, SMS/email-based, authorisation chains, etc
4	Could create personalised integrated financial workflows	Rule-based transactions (eg predefined limits/caps on the amount/volume), transaction interlinking, delegation, etc
5	Could choose what data to reveal, how and to whom	Virtual addresses, aliases based on time/payee/amount, zero knowledge proofs of personal data, etc
6	Could use any device for authorising transactions	Mobile phone, laptop, desktop, mixed reality headset, internet-of-things device, NFC tag and other form factors
7	Could send and receive anything of value in any unit, any amount, to anyone, anywhere	Any asset (registered/unregistered, regulated/unregulated, attested/unattested), any amount, anyone (any natural or legal person), anywhere
8	Could manage my assets with any asset manager of my choice	Banks, brokers, asset management companies, depositories, etc
9	Should be protected from fraud, abuse and bad actors	Know-your-customer and anti-money laundering, fraud monitoring/alerts, encryption and other secure cryptographic mechanisms, two-factor authentication, regulatory compliance checks, sanctions checks
10	Should be able to adhere to established legal norms	Banking law, securities law, taxation law, dispute resolution mechanisms, etc

Sources: Authors' elaboration.

The unified interledger protocol – a mechanism that ensures seamless interoperability across ledgers – is a cornerstone of the system. It allows users to open their account in any ledger and facilitate transactions between any ledger. The protocol ensures the integrity and consistency of transactions across different ledgers, providing finality through strong technical guarantees that once a transaction, such as an asset transfer, is completed, it is secure and irreversible.

For financial transactions, establishing trusted user identity is important. Trusted identity, crucial for both natural and legal persons, is anchored in verifiability, using digital signatures to accurately authenticate participants' identities. Features such as portability and permanence make these identities functional across various platforms. This ensures consistency while being adaptable for updates over time. Self-describing identities streamline access, eliminating external verification needs and making the system inclusive, bridging divides across technical capabilities and geographic locations. Moreover, identity is central to the enforcement of rules and policies within the system, necessitating features like traceability, accountability and observability directly tied to identity management. The "only submit it once" approach should be adopted as it specifically addresses the redundancy in submitting KYC and other identity documents, and these identity credentials can be attached to the user's profile for reuse.

Users can have their assets tokenised by token managers. Tokens within the Finternet are digital representations of assets that facilitate the ownership, transfer and management of value in a digital format. These versatile tokens can represent a diverse array of assets, ranging from traditional, tangible assets like real estate and artwork to intangible assets such as intellectual property and company shares, as well as inherently digital assets like digital currencies or virtual goods which exist on the unified ledger. Managed on the unified ledger and settled atomically, these tokens ensure that transactions are executed completely, reducing the risk of partial transaction failures and reinforcing the system's security and trustworthiness.

Each token on the Finternet is not only a digital representation of an asset but also carries core data and metadata that detail its characteristics and function, and the rules governing its use. The core data encapsulates essential information about the token, such as its type (eg whether it is a utility, security or currency token), ownership details and transaction history. Meanwhile, the metadata provide additional context and specifications about the token's functionality, including verifiable credentials, attestations and any specific rules or regulations it must adhere to. This metadata can outline restrictions on transferability, eligibility criteria for holders or compliance requirements based on jurisdictional laws or sector-specific regulations. By embedding both core data and detailed metadata, tokens within the Finternet offer a rich, multi-dimensional digital asset that can interact seamlessly within the digital ecosystem. This structure ensures that each token not only represents a piece of value but is also accompanied by a comprehensive set of information that enables secure, transparent and regulated interactions, enhancing the utility and governance of digital assets within the unified ledger ecosystem.

The process of tokenisation sits at the core of the Finternet. This is where assets are converted into digital tokens by token managers – entities that could range from central banks and commercial banks to asset management companies and private corporations. These digital tokens represent a direct link to the user's assets, encapsulating the principles of ownership, value and trust in a digital form. Each token is governed by a set of rules and regulations, ensuring that every transaction adheres to the stringent compliance and security standards set forth by the token managers. For example, tokenised deposits may follow regulations around KYC, transaction limits and cross-border restrictions, while tokenised shares could be subject to specific securities laws, detailing permissible buyers and sellers. Conversely, detokenisation allows users to convert digital tokens back to their original or traditional asset forms or to other digital formats, thereby unlocking their value for both conventional and digital use. A robust infrastructure of on-ramps and off-ramps supports the system, ensuring a seamless transition of assets between the digital and traditional economies. Tailored to accommodate the specific needs of different asset types, this setup adeptly handles the complexities of regulatory and registration requirements, effectively merging the traditional economic systems with the digital-first domain.

Token managers play a pivotal role in ensuring regulatory compliance for these tokens. Token managers might also maintain their own private or shared ledgers outside the Finternet, allowing for synchronisation between the unified ledger and their proprietary ledgers. This flexibility facilitates easy adoption, as token managers can issue tokens to users independently of the Finternet's internal asset management standards. It also provides mechanisms for the reproduction and recovery of tokens in case of loss. This comprehensive approach makes the digital economy more accessible, secure and user-friendly, catering to a broad spectrum of digital and traditional asset transactions. Additionally, users have the autonomy to manage tokens they create, acting as their own token managers. However, a key characteristic of the Finternet is that users can only produce tokens for themselves and not for others. This ensures that a user cannot produce unauthorised tokens on behalf of other token managers.

Enhancing transactions with trust and value-added services. As users transact within the Finternet, a suite of trust and value-added services augment their journey. These services, provided by entities such as attestors, verifiers, lockers and guarantors, infuse additional layers of security and credibility into the tokens. They play a crucial role in building a foundation of trust within the ecosystem, making transactions safer and more reliable. Trusted data takes a central role in transitioning to a digital-first financial landscape, where transactional information becomes transparent, immutable and directly

verifiable. This evolution marks a significant departure from traditional methods, establishing a framework where data integrity is paramount. Trusted data encompass a wide array of financial interactions, from transaction histories to asset ownership records, ensuring that each piece of data is securely recorded and resistant to tampering. This level of data reliability and security is instrumental in detecting and preventing financial crimes, enhancing the effectiveness of regulatory compliance and fostering trust among participants. It supports the development of predictive analytics and risk management tools, enabling proactive measures against fraud and other financial irregularities.

Trusted identity and data serve as cornerstones to facilitate dynamic contracting, substantially enhancing the network effects associated with asset tokenisation. Smart contracts automate the execution of agreements between parties securely and efficiently, streamlining transactions and fostering trust within the ecosystem.

Users can access a diverse ecosystem of applications to interact with unified ledgers. On the Finternet, applications will serve as versatile tools for individuals and businesses to manage an extensive array of financial aspects, encompassing banking, investments, insurance and beyond. Innovative applications will emerge, enabling the management of diverse asset types, such as real estate, paintings, digital assets and shares, offering a consolidated view of one's financial and asset portfolios. Individuals will benefit from these apps, which facilitate not only traditional financial transactions such as domestic and cross-border payments but also dealings in unique asset classes, enhancing the fluidity of personal and investment finance.

Moreover, these applications will enable personalised financial planning, with AI-driven insights suggesting optimal investment strategies, insurance coverage adjustments and savings plans tailored to individual goals and risk profiles. Businesses will access a suite of applications designed to streamline financial operations and enhance decision-making, manage cash flows, access varied financing options and optimise investment decisions. They will also engage in business-to-business (B2B) transactions, supply chain finance and real-time invoicing and payment processing. Together, these can foster a more dynamic economic environment.

A diverse range of developers and entrepreneurs can develop applications on the Finternet, each focused on solving specific problems for their target customers. By leveraging the underlying trust and robust infrastructure that the Finternet offers, they can innovate and create tailored solutions that meet the unique needs of various user segments.

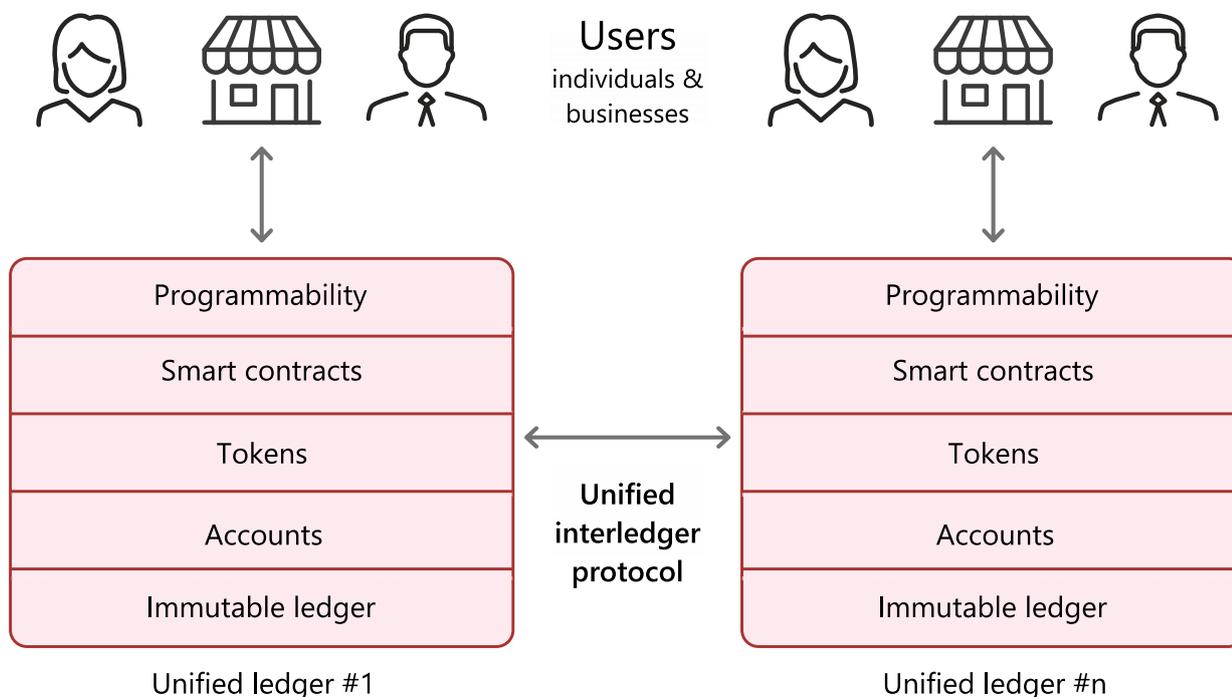
Across these diverse interactions, the applications in the Finternet will not only simplify financial management but also introduce levels of customisation and efficiency previously unattainable. This will enable all users to make informed decisions and achieve financial resilience and growth in an interconnected digital world. That, in turn, will ensure that everyone, from individuals to small and large businesses and society as a whole, benefit from these advances.

Unified ledgers: a secure, immutable and programmable backbone. Unified ledgers offer the capacity to manage a wide spectrum of assets, each distinguished by its legal status, market behaviour and security level. This diversity necessitates a nuanced understanding of asset classifications, ranging from registered assets, like real estate and vehicles, which benefit from legal protections and enhanced transactional security, to unregistered assets, such as privately sold artwork, which, despite offering privacy, may face challenges in ownership verification and liquidity. The distinction between regulated assets, like publicly traded securities, and unregulated assets, including some digital tokens, highlights the varying degrees of investor protection and market integrity. Moreover, the differentiation between attested assets, which provide verified assurances of authenticity, and unattended assets, which lack formal validation, underscores the importance of establishing clear guidelines to manage the risks of fraud and disputes. These distinctions are vital for designing regulatory frameworks that leverage the benefits of tokenisation while mitigating its inherent risks.

Diving deeper into the core characteristics of unified ledgers across different components such as programmability, smart contracts, tokens and account management, we have outlined an architecture diagram (Graph 9).

Architecture diagram for unified ledgers

Graph 9



Source: Authors' elaboration.

At its core, users leverage this system to perform a spectrum of financial activities, from transactions to asset management, facilitated by an array of user-friendly interfaces and applications. This system's hallmark – programmability – enables the customisation and automation of financial operations, allowing for the creation of bespoke financial products and services that cater to distinct user needs.

A pivotal advance within this system is its foundation of immutability. This characteristic heralds a departure from traditional ledger technologies fraught with inefficiencies and vulnerabilities, towards a unified, interoperable network of ledgers resistant to errors, fraud and unauthorised alterations. Immutability in unified ledgers ensures that once a transaction is recorded, it becomes irreversible, establishing a permanent, tamper-proof historical record. This shift from traditional databases, which cannot guarantee immutability across organisations, to technologies that do such as distributed ledgers, signifies a pivotal advance. The characteristic of immutability within these ledgers underscores the fact that the entities providing the ledger cannot alter or insert data post-recording. This reliance on technology over people, processes and legal frameworks to ensure the immutability of records denotes a critical evolution. Traditional databases lack this cross-organisational immutability, necessitating dependence on human oversight, procedural checks and legal protections to maintain data integrity. However, in unified ledgers, immutability is guaranteed by code, employing cryptographic methods that make altering history computationally infeasible. The linkage of each new record to the previous one requires exponential resources to change, making any attempt at tampering or historical revision nearly impossible. In an immutable ledger, mechanisms can be implemented to either block fraudulent transactions or issue compensatory ones as a form of reversal and rollback in cases of fraud.

The financial industry went through a similar leap in the last few decades with the advent of atomicity, consistency, isolation and durability (ACID) database technology. Initially, asset managers and financial institutions were reluctant to move from physical records to digital databases due to concerns

about data integrity, security and transaction reliability. ACID properties addressed these concerns by ensuring that transactions are processed reliably and securely: atomicity guaranteed that transactions are all-or-nothing; consistency ensured database rules are never breached; isolation maintained transaction independence; and durability assured that once a transaction is committed, it is permanent, even in case of a failure. This significant development made digital databases a trustworthy alternative to physical records, enabling efficient, scalable and accurate financial operations. This fundamentally transformed the banking and financial sectors. Unified ledgers with guaranteed immutability are now the next logical leap for record-keeping in financial services, and will shape the future.

Leveraging immutability, guaranteeing finality is a core characteristic of a unified ledger. Finality is crucial across legal, financial and technological domains as it provides certainty and stability, enabling parties to proceed with confidence knowing that actions or decisions are definitive and unalterable. It builds certainty for all. In unified ledgers, finality ensures transactions are irreversible once executed, cementing a trustworthy foundation for legal and economic activities. Rigorous pre-verification and fraud checks during transactions minimise the need for reversals, which, if necessary, are executed as compensatory actions by authorised entities. This process maintains the systemic integrity and dependability of a unified ledger environment, bolstering stakeholder confidence by ensuring transactions are conclusively recorded and enforceable.

Tokens within this ecosystem can represent a wide range of assets, from registered to unregistered, regulated to unregulated, and attested to unattested. Each category caters to different types of assets and legal frameworks.

For instance:

- **Registered tokens** represent claims of legally registered assets, such as real estate or vehicles, facilitating transactions that are compliant with specific registration standards.
- **Unregistered tokens** could be used for assets that do not require formal registration, like certain types of digital art or collectibles, offering a more flexible approach to ownership and exchange.
- **Regulated tokens** represent assets such as money or publicly listed shares and bonds that are governed by particular financial sector regulations.
- **Unregulated tokens** encompass tokens that operate outside the purview of traditional financial regulators, providing users with new forms of value exchange such as virtual assets in a game.
- **Attested tokens** contain verified proof of an asset's authenticity, such as product certifications, ensuring trust and credibility in digital interactions.
- **Unattested tokens**, on the other hand, represent assets or claims that do not have verified backing but still hold value within certain communities.

Moreover, the system's flexibility extends to the nature of the tokens themselves, which can be:

- **Fungible**, meaning they are divisible and interchangeable, like money, where each unit is identical to and interchangeable with another unit of the same type.
- **Non-fungible tokens (NFTs)**, which are unique and cannot be divided or interchanged, representing ownership of specific items such as digital art, unique digital goods or real-world assets with a digital certificate of ownership.
- **Bearer tokens** allow possession to equate to ownership, facilitating anonymous transactions and ownership transfers.
- **Non-bearer tokens** require identification of the owner for transactions, enhancing security and regulatory compliance for assets such as registered securities.

- **Tokens enabling blocking mechanisms** can be temporarily locked or restricted for transactions, akin to a cheque being put on hold, ensuring financial compliance or adherence to contractual conditions.
- **Non-blocking tokens** offer uninterrupted liquidity and transaction capability, akin to cash or e-cheques, providing users with continuous access to their assets.

Provisions for asset and token recovery in scenarios of loss are crucial, underscoring the importance of registered and regulated assets in providing comprehensive protections for asset owners.

Programmability through smart contracts. The essence of programmability within the Finternet is encapsulated in its sophisticated implementation of smart contracts. These contracts are essentially executable code that automate the execution of contractual agreements, thereby eliminating the need for intermediaries and significantly reducing the potential for disputes. Smart contracts on the Finternet can operate with remarkable flexibility, being deployable both remotely and directly on the ledger, which enables a wide array of transactional and contractual operations to be conducted with efficiency and precision. This capability is critical in ensuring that financial agreements are executed exactly as intended by the contracting parties, without the delays or errors that can occur in manual processes. The Finternet's smart contracts can govern a multitude of financial interactions, from simple transfers of value to intricate, conditional financial instruments and services. This level of automation and precision dramatically enhances the speed, efficiency and security of transactions within the ledger system.

Further augmenting the power of smart contracts is the Finternet's comprehensive support infrastructure, which includes a rich ecosystem of contract templates, policy frameworks and applets. This infrastructure provides developers and financial engineers with a robust toolbox for creating and deploying customised smart contracts tailored to specific transactional or operational needs. Smart contract templates offer a starting point for contract development, encapsulating common contractual arrangements and best practices. Policy frameworks ensure that contracts comply with relevant regulations and standards, embedding compliance directly into the transactional fabric of the ledger. Applets extend the functionality of smart contracts, enabling them to interact with external data sources, trigger events based on real-world occurrences or integrate with other digital services and platforms.

This innovative approach to digital contract execution not only underscores the Finternet's commitment to flexibility and reusability but also highlights its potential to revolutionise how contracts are created, executed and enforced in the digital age. By leveraging the programmability and automation capabilities of smart contracts, the Finternet offers a platform that can adapt to the evolving needs of the digital economy, ensuring that transactions are conducted with unparalleled efficiency, reliability and compliance.

A unified ledger meticulously records a broad spectrum of data. This centres primarily on transactions, ownership and tokens, while also extending its capabilities to encompass various additional elements. Here is an expanded overview of what a unified ledger typically records:

1. **Transactions:** Fundamental to its operation, the unified ledger documents transactions, detailing the transfer of tokens from one party to another. These transactions include critical information such as the sender's and receiver's identifiers, the transferred amount, the transactions timestamp and a unique transaction identifier.
2. **Ownership:** The ledger accurately tracks the ownership of digital assets. This ensures that every transfer and change in ownership is indelibly recorded, thereby providing a transparent and secure history of asset movements.
3. **Tokens:** The ledger includes comprehensive records of tokens, which are digital representations of assets or rights within the system. These records cover a wide range of token types, from those representing physical assets to digital rights and currencies, detailing their issuance, transfer and rules of engagement.

4. Smart contracts: Unified ledgers often support the deployment and operation of smart contracts, which are self-executing contracts with the terms of the agreement directly written into code. The ledger captures the deployment, operational rules and all interactions or transactions initiated by these contracts.
5. State changes: This involves recording updates to the condition or status of digital assets or accounts on the ledger, including alterations in smart contract variables or updates in digital wallets' balances.
6. Verifiable credentials: Capable of storing digital claims about an entity verified by a trusted issuer, the unified ledger uses these for applications such as identity verification, ensuring data integrity and privacy.
7. Cryptographic hashes and immutability-related data: the ledger employs cryptographic hashes as unique identifiers for data blocks, securing the unalterable linkage between them. Additionally, it records data underscoring its immutable nature, including cryptographic proofs and validations. This combined approach ensures the ledger's history remains intact, unchangeable and tamper-proof (see Box E).

Tracking fraud

In the complex landscape of financial fraud, practices like impersonation, circumvention and compromise highlight the multifaceted challenges faced by individuals and institutions alike (FinCen (2024)). Impersonation frauds exploit personal identities. Circumvention tactics bypass established standards and protocols. Compromises breach the security of accounts and systems. These categories encompass a broad range of fraudulent activities, from altering records and identity theft to cyber incidents and the abuse of insider access, each exploiting vulnerabilities for illicit gain. Against this backdrop, the Finternet stands as a formidable defence, offering advanced mechanisms to counteract these challenges.

Fraud at entry: preventing unauthorised access

- Identifiability and verifiability: The unified ledger enhances the ability to identify users and – where needed – to trace suspicious transactions and activities, making it significantly harder for impersonators to gain unauthorised access. By embedding advanced identity verification mechanisms that leverage biometric data, real-time authentication and digital signatures, the system ensures that only legitimate users can enter, and protects users from identity theft.
- Embedding of regulatory rules into code: Automating compliance through smart contracts prevents circumvention of entry controls. Regulatory requirements, such as KYC and AML/CFT standards, are programmed into the system, ensuring that all users meet strict criteria before being granted access.

Fraud once within the system: safeguarding against internal threats

- Observability and auditability: Once users are within the system, automated monitoring and real-time alerts for unusual activities help to detect internal fraud. The system's observability ensures that any attempt to manipulate transactions or records is immediately flagged, while auditability allows for detailed examination of actions when needed, enhancing accountability.
- Immutability and verifiability: The immutable nature of records within the unified ledger prevents alterations, ensuring that once a transaction is recorded, it cannot be changed or deleted. This verifiability deters insider fraud and abuse, as any fraudulent attempt to alter records will be easily detected and irrefutably traced back to the perpetrator.

Advances in cryptographic and ledger technologies

The financial sector has extensively leveraged cryptographic technologies, particularly encryption, to safeguard sensitive data, secure online transactions and ensure the confidentiality and integrity of financial communications. Encryption protocols like SSL/TLS are used to protect data transmitted over the internet, preventing unauthorised access and data breaches. The Advanced Encryption Standard (AES) secures data at rest, ensuring that stored financial information remains confidential and tamper-proof. Public Key Infrastructure (PKI) has played a pivotal role, serving as the backbone for both encryption/security and the integrity of digital records. PKI utilises a two-key asymmetric system, where a public key is used for encryption and a private key for decryption. This framework secures sensitive data in transit and also underpins the authenticity and integrity of digital records through digital signatures.

Digital signatures, enabled by PKI, inherently facilitate non-tamperability in digital transactions and records. By providing a secure means to verify the identity of transaction participants, they ensure that any data or records involved remain unaltered after signing. This verification process is key to maintaining data integrity, as any tampering with the content would invalidate the digital signature. Consequently, this mechanism not only protects against unauthorised modifications but also establishes non-repudiation, making it impossible for the signatory to deny their action or the authenticity of the signed document, thereby reinforcing trust and security in digital interactions.

Leveraging digital signatures, verifiable credentials and attestations, as standardised by the World Wide Web Consortium (W3C), bolsters the non-tamperability and verifiability of digital transactions. These credentials, which include examples like digital passports, educational degrees and professional certifications, are signed by trusted issuers and can be verified easily across platforms. Verifiable attestations, such as employment history confirmations or credit score validations, support these credentials by providing trusted evidence of the claims made. This system ensures secure, reliable identity verification and data integrity, streamlining the verification process, reducing fraud risks and enhancing efficiency in digital ecosystems.

Recent advances in identity data-sharing, such as Self-Sovereign Identity (SSI), empowers individuals to control their personal identity data, enabling them to share it securely and as needed. Beyond identity data, technologies like zero-knowledge proofs (ZK proofs) and multi-party computation (MPC) could also help to safeguard privacy and confidentiality in data-sharing. ZK proofs allow one party to prove to another that a statement is true without revealing any information beyond the validity of the statement itself. MPC enables multiple parties to jointly compute a function over their inputs while keeping those inputs private, enhancing the security and confidentiality of data-sharing.

Going beyond data-sharing, we can incorporate concepts such as tokens, programmability, composability and, in some cases, immutability into the regulated financial system, drawing from technological developments with hashing, merkle trees, smart contracts and various distributed ledger technologies (such as Hyperledger, Ethereum, etc).

In sum, these developments represent a transformative shift in the way trust is established, enabling massive network effects and unlocking new interactions across various sectors, thus redefining the dynamics of digital and economic exchanges. This is an indicative list, and we are at the threshold of many more advances. As technologies continue to evolve, it is critical not to get locked into specific solutions and instead design for evolvability, ensuring adaptability to future changes and innovations. Moreover, we must look to leverage the best technological advances while keeping in mind consumer protection, balancing innovation with the safeguarding of users' rights and interests.

Addressing social engineering attacks

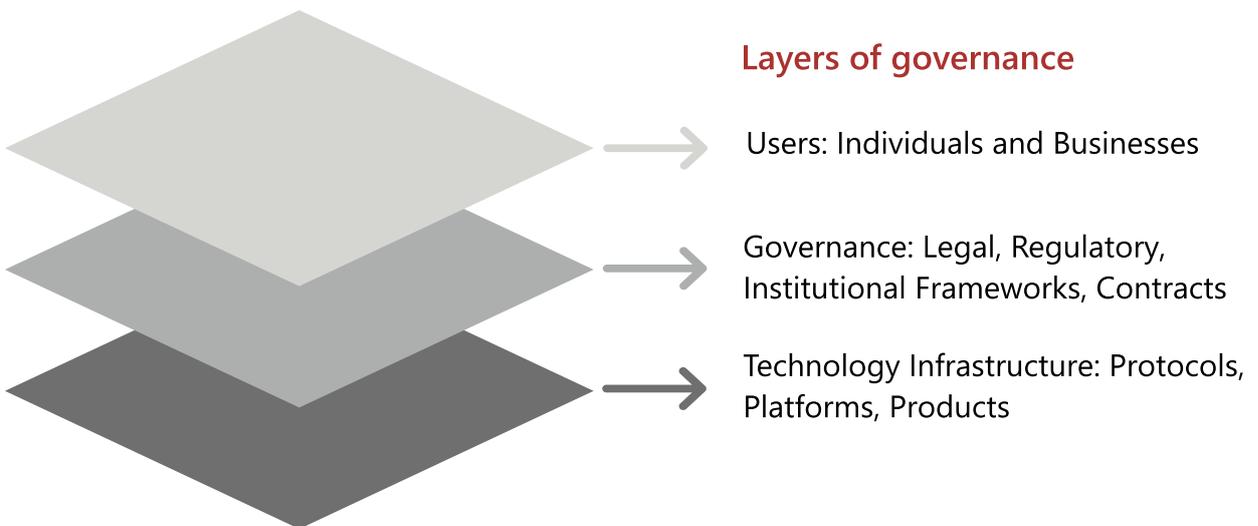
- Educational programmes and behavioural analytics: While technological safeguards are vital, educating users on the risk of social engineering attacks is equally important. Behavioural analytics can be employed to detect patterns indicative of social engineering, such as unusual transaction requests or atypical access patterns, triggering additional verification steps.
- Multi-factor authentication and dynamic permissions: Implementing multi-factor authentication and dynamic permission settings for transactions can mitigate the risk posed by social engineering. By requiring additional authentication for sensitive actions and adapting

permissions based on risk assessment, the system can prevent unauthorised transactions even if a user is manipulated.

As outlined above, the Finternet represents a significant advance over traditional record-keeping methods, which were susceptible to fraudulent alterations of individuals' property records and other forms of financial deceit. The Finternet's approach to combating fraud – through advanced technological safeguards, regulatory compliance embedded into code, and a strong focus on user education against social engineering attacks – offers a comprehensive solution to the pervasive challenges of impersonation, circumvention and compromise. This secures the financial ecosystem against both external and internal threats.

Multi-layered approach to governance

Graph 10



Source: Authors' elaboration.

The Finternet is designed to be an inclusive and open ecosystem that caters to a wide spectrum of participants, including individuals and businesses. This inclusiveness ensures that the benefits of digital financial transactions and asset management are accessible to all, fostering economic participation and innovation across various sectors. For users, the system being open to all underpins a foundational principle of equitable access, democratising financial services and ensuring that individuals and businesses, regardless of size or sector, can leverage the Finternet for their transactions and asset management. This approach, however, does not compromise the importance of adhering to established norms; all participants are subject to regulatory, legal and institutional frameworks that ensure the system's integrity and security.

On the technological front, making the infrastructure open to all encourages a culture of innovation and collaboration. By allowing a wide range of developers and entrepreneurs to engage with and build upon the Finternet's protocols, platforms and products, the system fosters a rich ecosystem of financial and non-financial applications. This openness not only accelerates technological advances within the Finternet but also ensures that the system can adapt to evolving user needs and global technological trends, maintaining its relevance and utility.

Governance within the Finternet is intricately crafted, automating regulatory compliance and enforcement at the token level through the pivotal role of token managers. These managers are the custodians of compliance, intricately weaving legal and regulatory mandates directly into the architecture of each token. This token-centric governance approach not only makes the system's oversight more effective and streamlined but also ensures that governance is dynamically responsive to the evolving landscape of digital assets and transactions. Each token, regardless of its nature or origin, is held to the

highest standards of security, legality and transparency, underpinned by a governance model that skilfully balances the principles of openness and stringent regulation.

Sophisticated technological solutions enhance the governance model. Non-repudiability ensures unequivocal accountability for all actions within the ecosystem, reinforcing the integrity of transactions. Auditability enables rigorous verification of compliance and integrity across the board, assuring adherence to legal and regulatory frameworks. Observability provides stakeholders with real-time insights, facilitating swift and efficient dispute resolution and proactive issue management. Moreover, the innovative “policy as code” concept transforms complex legal and regulatory directives into executable code embedded within tokens, automating compliance in an unprecedented manner. This advanced governance toolkit ensures the Finternet not only meets but exceeds the requirements for a secure, transparent and compliant digital financial environment, fostering an ecosystem where innovation and growth are nurtured within a framework of trust and accountability.

Effective implementation of the technology will be driven by use cases that benefit society

Embarking on the journey towards unified ledgers requires a strategic approach that acknowledges and addresses the concerns of all stakeholders involved. The key to successful implementation lies in selecting starter use cases. These should leverage what exists within a society, seamlessly integrate with current habits and incentives to minimise resistance (prioritising low-friction, high-impact initiatives) and cater to the needs and expectations of a broad range of stakeholders. It is crucial to identify and focus on areas where shared goals among individuals, regulators and market players exist, facilitating a smoother transition towards widespread acceptance and adoption. By embracing a proactive stance that ranges from harnessing enthusiasm to mitigating scepticism, the aim should be to showcase concrete benefits that resonate with the interests and alleviate the primary concerns of all parties.

3.3 Regulatory and legal considerations

Real world deployment of the Finternet, including unified ledgers, will require the development of a robust legal, regulatory and governance framework. Such a framework is essential to protect participants and preserve the integrity of the financial system. Without these guard rails, the Finternet will fail to earn the trust of consumers and businesses, and society as a whole will not reap the benefits that new digital financial technologies can offer. It is incumbent on governments and other public institutions to urgently address the unresolved regulatory and legal questions. It would be unfortunate if unclear or outdated legal frameworks unnecessarily delayed the long-overdue advance of the financial system. The work to address these issues should begin in earnest. And it should proceed at pace.

A basic starting point is that existing laws and regulations should apply to participants and assets in the Finternet. Unified ledgers and related infrastructure should not provide venues to circumvent laws or to engage in regulatory arbitrage. An implication of this is that jurisdictions do not need to create an *entirely* new bespoke legal framework to deploy unified ledgers. Indeed, the principle of technological neutrality suggests the authorities should seek to align the legal treatment of similar financial assets being transacted in different venues to the greatest degree possible. This consideration may be particularly relevant for EMDEs looking to deploy unified ledgers, where the capacity to develop entirely new legal frameworks may be limited.

Nonetheless, the development of unified ledgers does raise novel legal and regulatory issues. Among the most fundamental is the question of whether central banks have the authority to issue tokenised central bank money. As recently as 2020, the legal frameworks of around 80% of central banks were either unclear on this point or specifically barred central banks from issuing tokenised central bank money (Bossu et al (2020)). Regardless of whether or not central banks ultimately choose to issue tokenised central bank money, this uncertainty needs clarification. Without a wholesale tokenised central bank asset at its core, the future financial system will ultimately rely on legacy architecture to settle financial transactions. This would undermine many of the gains offered by unified ledgers.

Beyond questions of issuance, the legal status of the tokens that exist on unified ledgers requires clarification. For example, in some jurisdictions doubt exists about whether tokenised deposits would be treated as deposits, securities or some other form of financial asset under existing law (Deutsche Bundesbank (2023)). This, in turn, raises questions about the tax treatment of these assets, as well as whether they would be covered by deposit insurance if the issuing bank were to fail. More broadly, there is a need for careful examination of how existing legal requirements apply to assets that exist in a tokenised environment, taking account of the additional functionalities of tokenised assets. For example, in Switzerland legislative reform was needed to loosen a requirement for electronic signatures to accompany asset transfers before it was possible to trade tokenised assets on shared platforms (Garrido (2023)). This example also illustrates how the move to a tokenised financial system could help to simplify previously complex regulatory requirements.

Some jurisdictions may use the deployment of new financial infrastructures like unified ledgers as an opportunity to develop new legal norms. For example, they may wish to introduce measures to promote greater competition in the finance industry, such as through the promotion of open finance or mandating interoperability.

Deployment of unified ledgers also poses a range of complex governance questions. Fundamental issues include the ledgers' ownership, control of which financial institutions can participate in the ledger and decision-making regarding the types of assets and tokens that appear on the ledger and the rules governing their use. As with other financial market infrastructures, a number of alternatives suggest themselves, ranging from them being fully publicly owned and operated entities to relying entirely on private sector solutions, with public authorities' role limited to establishing the overriding legal framework and enforcing basic investor and consumer protection safeguards. Many intermediate solutions between these two extremes are also possible. Ultimately, the optimal choice may depend on the specific design and function of a given ledger, including the range of tokenised assets it includes. Different jurisdictions could also opt for different approaches in this regard, reflecting the characteristics of their own economies, financial markets and legal and regulatory structures.

Technological advances can help to strengthen legal and regulatory compliance within unified ledgers. Because tokens are programmable, it may be possible in some instances to embed compliance with laws and regulations, including AML and KYC requirements, within the code that governs the tokens and their transactions. The existence of a non-repudiable and verifiable digital audit trail within a ledger could also help to ensure accountability and aid investigation and dispute resolution.

But many regulatory and legal considerations are beyond the reach of technological solutions. This reflects the foundational principle that trust in the financial system does not come from technology but from the legal and regulatory framework that underpins it.

In many instances, there may be value in international cooperation in designing a legal and regulatory framework for unified ledgers. Indeed, for ledgers used to facilitate cross-border transactions, such cooperation at a multilateral level will be essential.¹⁴ Although the challenges in developing and aligning legal and regulatory frameworks on a cross-border basis are higher than those within a single jurisdiction, they are not insurmountable. Previous initiatives, such as the Continuous Linked Settlement (CLS) system, show that with sufficient will and flexibility it is possible to establish mutually agreeable governance arrangements for cross-border financial arrangements. Nonetheless, until such systems are in place, authorities may face a trade-off between delivering an improved domestic financial system in the near term and realising the larger gains from more seamless and integrated global financial markets in the longer term.

¹⁴ Without some form of multilateral agreement, interlinking of individual country unified ledgers to enable cross-border payments would require more than 193 x 193 new bilateral agreements, a near impossible task.

4. Design principles

As the above discussion has highlighted, there is no single path to building a Finternet centred around tokenised financial architectures and unified ledgers. Policymakers will face many choices, including those relating to unified ledgers' scope, technology, access and ownership. Jurisdictions will naturally differ in their approaches, reflecting their own unique circumstances.

Some characteristics are non-negotiable, however. In what follows we propose eight key design principles and explain their rationale. We believe that by following these principles, unified ledgers can achieve a balance between robust governance and operational efficiency, while fostering an environment ripe for innovation and growth.¹⁵

Principle #1: Users at the centre

The key rationale for developing the Finternet is to offer individuals and businesses access to the greatest possible range of financial services, in the most flexible way and at the lowest possible cost. The best way to achieve this goal is to prioritise the needs and wants of the system's users. In most cases, user priorities should guide technological and regulatory choices, not the other way round.

Principle #2: Interoperability

It is neither feasible nor desirable to build a single unified ledger to encompass all financial assets and transactions. Accordingly, unified ledgers will need to be interoperable with other parts of the financial system. Ideally, such interactions will be seamless, enabling functionality across different protocols, platforms and products. Interoperability will facilitate the creation of a "network of networks" to connect the diverse array of specialised networks that characterises modern financial systems.¹⁶ Such an interconnected framework significantly enhances the functionality and reach of each participating network. The emergence of such a complex system requires the development of consistent standards and protocols to enable interoperability, while preserving the autonomy and integrity of each subsystem. This strategic, interconnected model aims to foster a financial ecosystem that is both more integrated and resilient, effectively responding to the sophisticated demands of modern finance.

Principle #3: Evolvability

The technological advances that motivate the development of unified ledgers will eventually be superseded. Accordingly, the Finternet should be able to evolve to accommodate future technological advances, while maintaining backward compatibility with existing systems where necessary. Such evolvability will facilitate continuous improvement and open avenues for innovation, by enabling new entrants to contribute meaningfully to the ecosystem's development. Adopting a pragmatic "+1" approach by leveraging existing systems as a foundation ensures a seamless transition towards more sophisticated technologies, balancing innovation with practical implementation.

Principle #4: Modularity

This principle highlights the importance of endowing the architecture with the capacity to evolve through discrete, independently modifiable layers, minimising disruption across the ecosystem. Further, providing extensive programmability within the infrastructure is essential, enabling users to tailor functionalities to their unique requirements, fostering a highly personalised and flexible environment.

¹⁵ As discussed at greater length in BIS (2023), unified ledgers are a new type of financial market infrastructure. The design considerations offered here are high-level principles from an architecture point of view and are meant to complement, not replace, the Principles for Financial Market Infrastructures (PFMI; CPSS-IOSCO (2012)).

¹⁶ In modern financial systems, each of these networks is dedicated to distinct domains and equipped with unique technological infrastructures, governance protocols and user ecosystems.

Principle #5: Scalability

The scope and range of participants on the Finternet is likely to expand over time. Conceivably, this growth could be non-linear, as the introduction of new users and products enhances the value of the entire network, encouraging further growth. Accordingly, unified ledgers need to be able to accommodate such growth without compromising security and functionality.

Principle #6: Division of labour and competition

Public and private sector institutions both have roles to play in developing the Finternet. For the public sector, a key objective is to provide the “rails”, which could include the core infrastructure, rules and regulations on which private financial institutions can operate. A key objective will be to promote healthy competition between private actors through open platforms, and a level playing field can support innovation and lower costs for end users by reducing rents. In this regard, policymakers should bear in mind that in today’s system, inefficiencies are often someone’s profit; accordingly, some resistance is to be expected and will require careful compromises. Creating an innovation-friendly atmosphere that supports combinatorial innovation allows for the blending of different technologies and methodologies, paving the way for breakthrough advances.

Principle #7: Inclusiveness and accessibility

Innovators are keen to leverage infrastructure with the ultimate goal of making financial activities universally accessible, affordable and inclusive, ensuring no one is left behind. In the current financial services ecosystem, several constraints have emerged, presenting unique challenges yet opening avenues for innovation and improvement. Notably, the implementation of new technologies and systems has been met with high costs and operational delays, contributing to a slower pace of adoption across the board. This situation has inadvertently limited the empowerment of individuals within the financial ecosystem. The potential for widespread network effects – which could significantly enhance user empowerment and system efficiency – remains largely untapped. Such challenges underscore the need for a re-imagined approach that prioritises affordability, flexibility and inclusiveness in digital financial services. The architecture should aim wherever possible to serve any sector, be accessible on all devices and cater to a wide range of purposes (from personal finance to institutional operations) while offering a choice of custodial services. It should support multiple data standards and integrate methods for determining the quality of assets, and respect existing legal norms.

Principle #8: Security and privacy

Last but certainly not least, the security of the infrastructure is a fundamental design principle. This pertains to security both vis-à-vis users and of the infrastructure at large. For one, a digital financial infrastructure should have adequate safeguards for data privacy and commercial secrecy, while ensuring system integrity by guarding against money laundering, financing of terrorism and fraud. Moreover, strong institutional and legal safeguards to ensure operational and cyber resilience of the infrastructure should remain always and everywhere a first-order concern. As discussed in BIS (2023), the public sector has a pivotal role to play in this regard given the public good nature of cyber security.

5. Conclusion

In this paper, we have laid out a vision for the future financial system. The vision, which we call the Finternet, puts users of financial services firmly at the centre. They will have access to a wider and more bespoke selection of financial services and assets, and will have more flexibility in how they manage their financial affairs. Financial services will be cheap, secure and near-instantaneous. And they will be available to anyone. The financial system will help individuals and business to manage risk, safeguard their savings and

invest in a better future. While all jurisdictions stand to benefit, the gains could be particularly large for EMDEs, where lack of access to financial services is currently most pervasive, and the possibility to leapfrog to the technological frontier is the greatest.

We have also provided a blueprint to guide policymakers seeking to translate this vision into reality. We identify three necessary components: an efficient economic and financial architecture, the application of cutting-edge digital technology and a robust legal and governance framework. We see unified ledgers as a promising vehicle to deliver on all three. In particular, by bringing together multiple financial assets in a single venue, they offer the possibility of vastly reducing the need for lengthy messaging and clearing processes, thereby delivering more efficient and reliable services for users.

At the same time, we acknowledge the considerable uncertainty about precisely which innovative technologies will best serve as a basis for the future financial system, and their best use. Turning the vision of the Finternet into reality requires experimentation. Only then can we have a full measure of the challenges and the best strategies to overcome them. Many central banks are engaged in this necessary process of trial and error. The lessons from these projects are an invaluable public good towards realising the shared vision of a more efficient, transparent and inclusive financial future. Box F reviews one of the most recent examples, namely Drex in Brazil, while Box G reviews contributions from the BIS Innovation Hub related to unified ledgers. Needless to say, many private sector initiatives are also under way.

Box F

Brazil's Drex: putting the unified ledger into practice

Following the wide success of Pix (see Box B), the Central Bank of Brazil (BCB) has launched Drex, a project for a digital Brazilian real. Drex is part of the broader BC# agenda, which aims to foster competition in the financial system through innovation. Also included in that category are Pix, the open finance initiative and internationalisation of the real (Campos Neto (2023)). The Drex ecosystem includes Drex (central bank money), the Drex platform, its participants and its rulebook and regulation.

The Drex platform is a unified ledger where wholesale tokenised central bank money, deposits, e-money and treasuries coexist. The initiative is a collaboration of the BCB, the Brazilian National Treasury, the Brazilian Securities Exchange Commission and the private sector. It builds on a public-private partnership and leverages the strengths of the current two-tier monetary system. A key component of the early phase of the project is the so-called Lift Challenge, sponsored by the BCB, with selected use cases proposed by banks, payment institutions and other market participants. These include the development of delivery versus payment (DvP), payment versus payment (PvP), the internet of things (IoT) and decentralised finance (DeFi), among others.

While Drex is perhaps the most advanced initiative towards making unified ledgers a reality, it is certainly not the only one. Other pioneers include the Bank of Korea, the Monetary Authority of Singapore and the seven central banks that teamed up with the BIS Innovation Hub in Project Agorá.

A key question is how to proceed. One approach would be to adapt different parts of the financial system sequentially in a series of incremental steps. There is merit to this approach, particularly in jurisdictions where financial services are already reasonably efficient and widely accessible. Incremental progress could lower upfront costs, ensure compatibility with legacy systems and help to secure buy-in from incumbent financial institutions.

But incremental fixes have their limits. Building a new financial system on old foundations naturally constrains what it can deliver. Over time, the constraints will bind more tightly – as the financial system inches forward, the technological frontier will drift ever further away. For this reason, we are inclined to favour a more transformative adjustment, involving a fundamental rethink of financial infrastructure to ensure that it can deliver the full benefits that digital technology can offer.

Regardless of how one proceeds, it is time for a “Neil Armstrong” moment – the small first step that represents a giant leap for the financial system. For this, public institutions can play a catalytic role in

helping financial system development progress from individual experimentation to joint innovation. We know where we need to go. We have the tools to get there. Now is the time to take the first step.

Box G

Contributions from the BIS Innovation Hub to an architecture for unified ledgers

The implementation of the vision of unified ledgers requires a wide variety of functionalities and technologies interacting with each other to fulfil its final objective of seamless, integrated financial services. This complex endeavour is unlikely to be completed by a single entity or with a single solution. Most likely, it will require wide collaboration among stakeholders using nascent and existent technologies.

The BIS Innovation Hub stands out as a leading reference among the numerous institutions actively contributing to the evolution of financial services through the exploration of innovative technologies. Its work has explored many of the functions that would be required for the implementation of unified ledgers: interoperability, efficient and cross-asset settlement, accessibility, cyber security, fraud and anti-money laundering controls, digital identity and functional programming of money. These initiatives, designed for both domestic and international contexts, have benefited from a mix of public and private sector contributions.

- On **interoperability**, BIS Innovation Hub projects have focused on connecting existing systems and new ones such as central bank digital currencies (CBDCs). Across borders, Project Nexus created a blueprint to connect domestic fast payment systems. Projects Jura, Dunbar, mBridge and Mariana explored how to connect wholesale CBDCs using a common platform, and Project Icebreaker looked at retail CBDCs using a hub and spoke model.
- **Efficient settlement** has been explored in CBDC and tokenisation projects as well as in traditional financial market infrastructures. Beyond the atomic settlement of cross-border payments exemplified in the cross-border CBDC projects listed above, other experiments broadened the settlement use cases with payment versus payment (PvP) functions that allowed FX settlement (Projects Mariana and Agora for tokenised deposits) and delivery versus payment (DvP) (Projects Helvetia, Jura and Promissa). Efficient settlement is also explored in projects focused on improving traditional FMIs (Projects FuSSE and Meridian).
- **Accessibility** projects span a wide range of use cases. For example, on the retail CBDC side, Project Rosalind makes use of standardised APIs to connect central bank ledgers and make private sector systems simpler. Project Polaris explored offline accesibility for retail CBDCs, a crucial requirement in many jurisdictions.
- **On cyber security**, Innovation Hub projects have helped shed light on cyber risks in a future era of quantum computers (Projects Leap and FuSSE) and experimented with developing CBDC systems that are cyber secure (Project Sela) or that preserve transaction privacy while being resilient to quantum computer attacks (Project Tourbillon). In addition, Project Polaris developed handbooks that explain the cyber security landscape and best practices in this space.
- The use of technology has featured in Innovation Hub projects to help **green and secure the financial system**. For example, Project Aurora is helping to reduce the flow of illicit transactions. Project Hertha makes use of AI to help identify financial crime patterns while preserving user privacy within a real-time payment systems. On the green finance side, Project Genesis aimed to reduce the negative environmental externalities to the planet by understanding the process of issuing green bonds. In addition, projects have explored the use of **digital identity** and signatures for preserving privacy (Projects Tourbillon and Aurum).
- Finally, the power of **automation through programming** has been explored by embedding regulatory restrictions in the code (Project Mandala), and by supporting trade finance (Project Dynamo).

These projects have generated, or are generating, useful lessons and solutions that could help bring the vision of unified ledgers to reality. While some of the projects focused on individual functions, others have brought several functionalities together. Going forward, it is important to explore the challenges and opportunities related to the functional integration among these elements and with other developed by different entities.

Glossary

Atomic settlement: instant exchange of assets, such that the transfer of each occurs only upon transfer of the other.

Auditability: the property that allows digital transactions and activities to be independently verified and audited for integrity, accuracy and regulatory compliance.

Composability: the capacity to combine different transactions or operations on a programmable platform.

Central bank money: money issued by the central bank, such as banknotes, coins, central bank reserves or (more recently) tokenised central bank money.

Commercial bank money: money issued by commercial banks in the form of deposits.

Confidentiality: the assurance by a system that sensitive information is disclosed only to authorised users, safeguarding data privacy and security.

Counterparty risk: the risk that one or more participants will not provide the money or financial assets to deliver on their side of the transaction.

Cross-border payment: a payment in which the financial institutions of the payer and the payee are located in different jurisdictions.

Detokenisation: the process of converting recorded claims (represented as tokens) on a programmable platform back into their original claims on financial or non-financial assets within a traditional ledger.

Digital-first approach: a method for developing payment and other systems that starts from digital technologies and puts these at the centre of all business operations and customer interactions.

Digital identity: a set of information about a person or company that can be found and used online.

Digital public infrastructure: interoperable, open and inclusive digital systems, supported by technology to enable the use and provision of essential, society-wide, public and private services.

End users: individuals, households and firms that are not participants in a platform or payment system.

Enforceability: the mechanism by which a system can automatically ensure adherence to legal agreements, policies or regulatory requirements, reducing the need for manual enforcement.

Fast payment system: a payment system in which the transmission of the payment message and the availability of final funds to the payee occur in real time or near-real time and on as near to a 24-hour and seven-day (24/7) basis as possible.

Finality: the moment at which funds or assets, transferred from one account to another, officially become the legal property of the receiving party.

Financial health: the extent to which a person or family can successfully manage their financial obligations and have confidence in their financial future.

Financial inclusion: access to and use of transaction accounts and related financial products such as savings, payment cards, loans and insurance.

Finternet: interconnected financial ecosystems that place individuals and businesses at the centre of their financial lives, powered by open, interoperable technologies and protocols.

Infrastructure services: existing national or sector-specific infrastructure, including identity systems, digital signature certificate systems, connectivity, registrars and registries, and digital public infrastructure, along with any other reusable services available within a country.

Interoperability: the capacity of diverse digital systems, platforms and applications to seamlessly exchange information, ensuring compatibility across varying technological frameworks.

Immutability: the characteristic of a system that prevents alteration or deletion, ensuring permanent and tamper-proof record-keeping.

Ledgers: record-keeping systems that guarantee finality and immutability by ensuring that once transactions are recorded, they cannot be altered, deleted or reversed.

Network of networks: a set of networks where each of these is dedicated to distinct domains and equipped with unique technological infrastructures, governance protocols and user ecosystems.

Non-repudiability: a security characteristic ensuring that users cannot deny the authenticity of their actions, supported by irrefutable evidence such as digital signatures or tamper-proof transaction logs.

Observability: the characteristic of a system that provides visibility into necessary transactions and operations, essential for policymakers, regulatory agencies and participants to effectively monitor for operational efficiency and compliance, detect fraud and ensure accountability across the ecosystem.

Programmability: a feature of platforms and other technologies whereby actions can be programmed or automated.

Programmable platform: a technology-agnostic platform that includes a Turing machine with an execution environment and a ledger and governance rules.

Smart contract: self-executing applications of programmable platforms that can trigger an action if some pre-specified conditions are met.

Token: a digital representation of value in a programmable platform. Tokens can be tokenised, ie derived from claims in traditional ledgers, or can be issued natively in the platform, ie "native" tokens.

Tokenisation: the process of recording claims on real or financial assets that exist on a traditional ledger onto a programmable platform.

Tokenised asset: a digital representation of a claim on an asset in a programmable platform.

Tokenised central bank money: a form of digital money, denominated in the national unit of account, which is a direct liability of the central bank.

Tokenised deposit: a digital representation of a bank deposit in a programmable platform. A tokenised deposit represents a claim on a commercial bank, just like a regular deposit.

Token manager: an institution that is responsible for the issuance (tokenisation, detokenisation), management and synchronisation of a token with their private ledger.

Tokenised network: a platform that operates, clears and settles with tokenised money, tokenised deposits, tokenised assets or any other form of token.

Turing machine: a finite automaton that can read, write and erase symbols on an infinitely long strip of tape.

Unified ledger (UL): a digital platform that brings together multiple financial assets as executable objects on a common programmable platform.

Unified Interledger Protocol (UILP): set of open protocols that defines the messaging specifications between different unified ledgers to ensure interoperability and finality of transactions between them.

Verifiable identity: a digital representation that enables verification of an individual's or entity's identity through digital means, employing cryptographic methods.

References

- Aguilar, A, J Frost, R Guerra, S Kamin, and A Tombini (2024): "Digital payments, informality and productivity", *BIS Working Papers*, forthcoming.
- Aldasoro, I, S Doerr, L Gambacorta, P Koo-Wilkens, and R Garratt (2023): "The tokenisation continuum", *BIS Bulletin*, no 72.
- Alonso, C, T Bhojwani, E Hanedar, D Prihardini, G Una and K Zhabska (2023): "Stacking up the Benefits: Lessons from India's Digital Journey", *IMF Working Paper*, no 23/78.
- Ardic Alper, O, G Galicia Rabadan, A Marin Espinosa, H Natarajan, T Piveteau, N Ramteke, A Sarkar (2023): *G20 Policy Recommendations for Advancing Financial Inclusion and Productivity Gains through Digital Public Infrastructure*. Washington DC, World Bank Group.
- Aurazo, J, H Banka, J Frost, A Kosse, and T Piveteau (2024): "Central bank digital currencies and fast payment systems: rivals or partners?", mimeo.
- Aurazo, J and C Franco (2024): "Fast payment systems and financial inclusion", *BIS Quarterly Review*, March.
- Banerjee, A V and E Duflo (2014): "Do Firms Want to Borrow More? Testing Credit Constraints Using a Directed Lending Program", *The Review of Economic Studies*, 2014, 81 (2), pp 572–607.
- Bank for International Settlements (2023): "Blueprint for the future monetary system: improving the old, enabling the new", *Annual Economic Report 2023*, Chapter III.
- Bech, M, J Hancock and W Zhang (2020): "Fast retail payment systems", *BIS Quarterly Review*, March, pp 28–9.
- Beck, T, L Gambacorta, Y Huang, Z Li and H Qiu (2022): "Big techs, QR code payments and financial inclusion", *BIS Working Papers*, no 1011.
- Boakye-Adjei, N, R Auer, H Banka, A Faragallah, J Frost, H Natarajan and J Prenio (2024): "Can central bank digital currencies help advance financial inclusion?", *Journal of Payments Strategy & Systems*, vol 17, no 4.
- Bossu, W, M Itatani, C Margulis, A Rossi, H Weenink and A Yoshinaga (2020): "Legal aspects of central bank digital currency: Central bank and monetary law considerations," *IMF Working Papers*, no 20/254.
- Carstens, A (2023): "The future monetary system: from vision to reality", keynote speech at the CBDC & Future Monetary System Seminar, Seoul, 23 November.
- Campos Neto, R (2023): "The BIS and Banco Central do Brasil relationship: lessons learned and challenges ahead", in *Central banking in the Americas: lessons form two decades*, pp 41–54.
- Cantú, C, J Frost, T Goel and J Prenio (2024): "From financial inclusion to financial health", *BIS Bulletin*, no 85.
- Committee on Payment and Settlement Systems and Technical Committee of the International Organization of Securities Commissions (CPSS-IOSCO) (2012): *Principles for financial market infrastructures*.
- Demirgüç-Kunt, A, L Klapper, D Singer and S Ansar (2022): *The Global Findex Database 2021*, World Bank.
- Deutsche Bundesbank (2023): "Digital money: options for the financial industry", *Monthly Report*, pp 17–32.
- D'Silva, D, Z Filková, F Packer and S Tiwari (2019): "The design of digital financial infrastructure: lessons from India", *BIS Papers*, no 106.
- Dupas, P and J Robinson (2013): "Savings Constraints and Microenterprise Development: Evidence from a Field Experiment in Kenya", *The American Economic Review*, vol 103, issue 5, pp 2196–2226.

Financial Stability Board (FSB) (2023): *Annual Progress Report on Meeting the Targets for Cross-Border Payments*.

FinCen (2024): "Financial trend analysis. Identity-related suspicious activity: 2021 threats and trends", Financial Crimes Enforcement Network.

Frost, J, P Koo Wilkens, A Kosse, V Shreeti and C Velasquez (2024): "Fast payments: design and adoption," *BIS Quarterly Review*, March.

Gambacorta, L, Y Huang, Z Li, H Qiu and S Chen (2022): "Data versus Collateral", *Review of Finance*, vol 27, issue 2, pp 369–398.

Garratt, R and H S Shin (2023): "Stablecoins versus tokenised deposits: implications for the singleness of money", *BIS Bulletin*, no 73.

Garrido, J M (2023): "Digital Tokens: A Legal Perspective", *IMF Working Paper*, no 23/151.

Jahan, S, J De, F Jamaludin, P Sodsriwiboon and C Sullivan (2019): "The Financial inclusion Landscape in the Asia-Pacific Region: A Dozen Key Findings", *IMF Working Paper*, no 19/79.

Karaivanov, A, B Mojon, L A Pereira da Silva and R M Townsend (2023): "Digital safety nets: a roadmap", *BIS Papers*, no 139.

Nilekani, N, P Varma and S Shetty (2024): "Finternet: Technology Vision and Architecture", mimeo.

Tiwari, S, S Sharma, S Shetty and F Packer (2022): "The design of a data governance system", *BIS Papers*, no 124.

World Bank (2023): "Remittance Prices Worldwide", *Quarterly Report*, Q1.

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