BIS

BIS Bulletin

No 72

The tokenisation continuum

Iñaki Aldasoro, Sebastian Doerr, Leonardo Gambacorta, Rodney Garratt and Priscilla Koo Wilkens

11 April 2023

BIS Bulletins are written by staff members of the Bank for International Settlements, and from time to time by other economists, and are published by the Bank. The papers are on subjects of topical interest and are technical in character. The views expressed in them are those of their authors and not necessarily the views of the BIS. The authors are grateful to Douglas Araujo, Claudio Borio, Stijn Claessens, Thomas Nilsson and Tara Rice for comments, and to Louisa Wagner for administrative support.

The editor of the BIS Bulletin series is Hyun Song Shin.

This publication is available on the BIS website (www.bis.org).

© *Bank for International Settlements 2023. All rights reserved. Brief excerpts may be reproduced or translated provided the source is stated.*

ISSN: 2708-0420 (online)
ISBN: 978-92-9259-648-4 (online)

Iñaki Aldasoro Sebastian Doerr Leonardo Gambacorta Rodney Garratt Priscilla Koo Wilkens

Inaki.Aldasoro@bis.org Sebastian.Doerr@bis.org Leonardo.Gambacorta@bis.org Rodney.Garratt@bis.org Priscilla.KooWilkens@bis.org

The tokenisation continuum

Key takeaways

- *Tokenising claims involves transforming them into tokens on a common programmable platform that combine a core layer, which contains information about the tokenised asset and its ownership, with a service layer embedding the platform's rules and governance.*
- *Tokenisation enables the automation of transactions involving money as well as financial and real assets, opening the way to the contingent transfer of claims and combinations of transactions via smart contracts.*
- *Economic, legal and technical challenges span a "tokenisation continuum" which describes the feasibility of tokenising traditional assets; gains are modest where tokenisation is easiest but the most valuable gains would involve the largest challenges.*

Several initiatives in the private and public sectors explore the potential benefits of tokenising financial or real assets. Tokenisation refers to the process of generating a digital representation of traditional assets on a programmable platform (FSB (2023)). By moving assets recorded on separated traditional ledgers to a common programmable platform, tokenisation could unlock benefits through greater automation, including faster, cheaper and more convenient transactions. These potential gains rest on technological advances from programmability, which enable the use of smart contracts, thus opening the way to the bundling of transactions (so-called composability).[1] These new ways of contract execution can potentially expand the universe of possible contracting outcomes, allowing transactions that are currently unfeasible due either to incentive or information problems.

This Bulletin is a primer on tokenisation and its key elements. Tokenisation can reap gains through transaction automation and new types of asset transfer, but it raises economic, legal and technical issues. These challenges define a "tokenisation continuum" that represents the trade-offs involved in the tokenisation of different kinds of traditional assets. The tokenisation continuum suggests that where tokenisation is easiest, per-unit gains are likely to be modest. Efforts that concentrate initially on identifying the assets that are most suitable for tokenisation may yield the largest benefits, especially when the asset is traded in large volumes.

Tokenising traditional assets

The process of tokenisation contains three key elements: assets, ledgers and tokens.

Assets are resources with inherent economic value owned by an individual or an organisation. They can range from everyday objects, such as a couch, to a real estate property or a share of a mortgage-backed security. Some assets require the representation of a record of property rights on a ledger (eg a

[1] Smart contracts refer to self-executing code triggered when pre-specified events occur. Composability refers to the capacity to combine different smart contracts in a system, such as decentralised finance (DeFi) protocols (BIS (2022), FSB (2022)).

house, which is registered in property registries). Others do not require such representation to keep track of ownership (eg a couch inside a house).

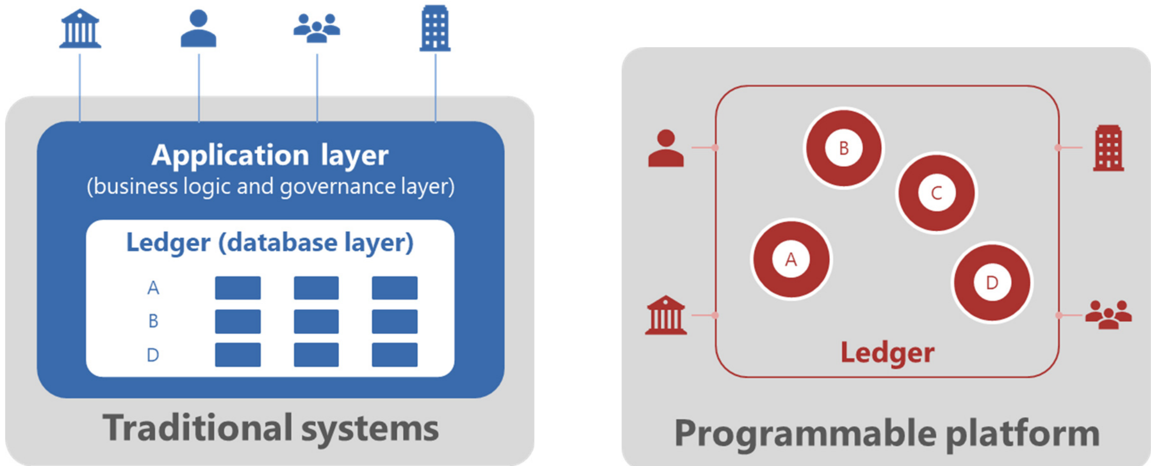
Ledgers record information about ownership. Traditional ledgers rely on two segregated components: the *database* layer stores records of assets, while the *application* layer incorporates centralised logic and governance rules into the system and manages the recording, updating and deletion of assets on the ledger (Graph 1.A). In traditional ledger systems, trust in the accuracy of the records relies on trust in the ledger's operator. This trust is usually supported by institutional arrangements and legal frameworks that have evolved over time. One early example is the double-entry bookkeeping system developed by Venetian bankers (the trusted authority), which ensures that each transaction is recorded by two parties, thereby helping to assure accuracy and prevent fraud. Today, external audits or licensing requirements for notaries serve a similar function. Think for example of a corporate bond held by Sam in a central securities depository. The database layer contains information on Sam's holdings of that corporate bond, such as the name of the issuer, the amount and the coupon. The application layer determines how Sam's holdings of the bond will fall when he sells it to Caroline and how ownership is transferred. In all this, Sam and Caroline need to trust the operator of the central securities depository to transfer ownership.

Advances in technology have produced a new type of "programmable ledger" that allows for the use of smart contracts and composability.[2] Any transaction on such a ledger is done according to pre-agreed standards, whether in the form of fund transfers, locking of assets as collateral or other functions (Graph 1.B). Transactions on a programmable platform require tradeable digital assets that are specific to that platform. They must comply with the platform's standards and the rules of its smart contracts. These digital assets are called **tokens**.

Traditional and programmable ledger systems — Graph 1

A. Traditional ledger systems segregate the records from the rules that govern the recording/updating of assets

B. Programmable platforms rely on tokens without the need for a centralised application layer



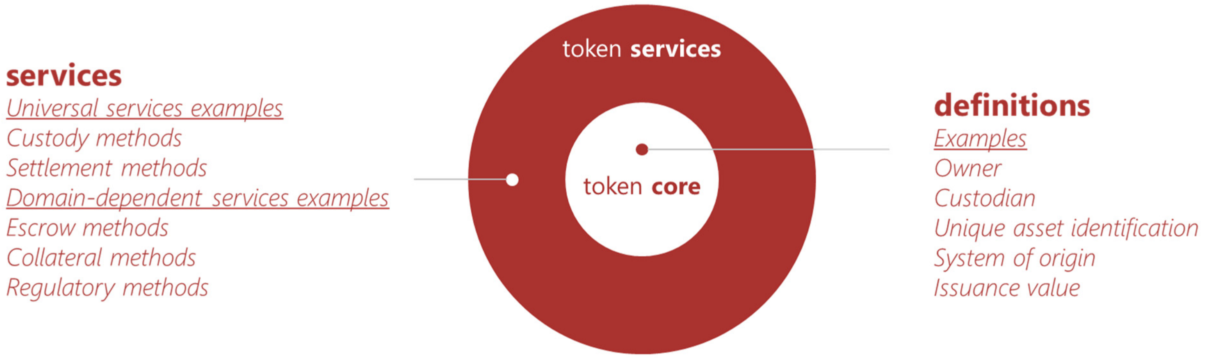
Source: Authors' elaboration.

Tokens combine core and service layers (Graph 2), which resemble the segregated database and application layers in traditional platforms. The *core layer* contains the information to uniquely identify and

[2] The rise of crypto, and in particular the Ethereum blockchain, introduced programmable ledgers built on distributed ledger technology (DLT). Most DLT platforms do not require a centralised intermediary to keep track of transactions and ownership but rely on a decentralised system sustained by fees (Boissay et al (2022)). Tokens and smart contracts can also be used on a programmable platform with centralised governance or transaction validation (Garratt and Shin (2023)).

define the asset and its owner. The *service layer* specifies the rules and logic governing a token's use on the platform (eg in smart contracts). These services can be "universal" and apply to all tokens on the platform, or they can be "domain-dependent" and specific to certain types of asset transaction. For instance, on the Ethereum blockchain – the first to introduce programmability – a token following Ethereum's ERC-20 standard[3] includes in its core layer data such as its name, the owner and the number of tokens in circulation. Its service layer contains the types of allowed transaction, for example locking the token in a liquidity pool.

The anatomy of a token: core and service layer — Graph 2



Source: Authors' elaboration.

Tokenisation is the process of recording claims on real or financial assets that exist on a traditional ledger onto a programmable platform. This requires that an asset is transformed into a token with core and service layers in full accordance with the rules of the importing programmable platform. The process occurs through so-called **ramps**, which apply the necessary computational transformations from traditional systems architecture to new ledger technologies (Graph 3.A).[4] Ramps lock assets in their platform of origin as collateral for the tokens that are issued on the programmable platform. They perform a role analogous to that of bridges connecting one distributed ledger technology (DLT) platform to another (Graph 3.B).

Benefits and challenges to tokenisation

The combination of core and service layers within each token constitutes a key advantage of tokenisation. Integrating the records of assets and transaction validation into a single process allows for the use of token-specific smart contracts; it also provides the flexibility to customise tokens for selected transactions without making changes to the rules of the platform itself. This stands in stark contrast to traditional ledger systems, where database and application layers are separate and centrally managed.

Tokenisation could deliver gains in two ways. First, through automation it could greatly speed up transactions and increase efficiency by ensuring all parts of a transaction occur simultaneously, in what is called atomic settlement. Second, it opens up new ways to transfer assets that are currently not feasible, potentially expanding the universe of possible contracting outcomes via composability.

In the case of payments, tokenisation could increase speed and transparency and lower costs, especially in the cross-border context. To make a digital payment, users currently have to instruct the

[3] ERC-20 is the technical standard used for creating fungible tokens compatible with Ether (ETH) on the Ethereum blockchain.

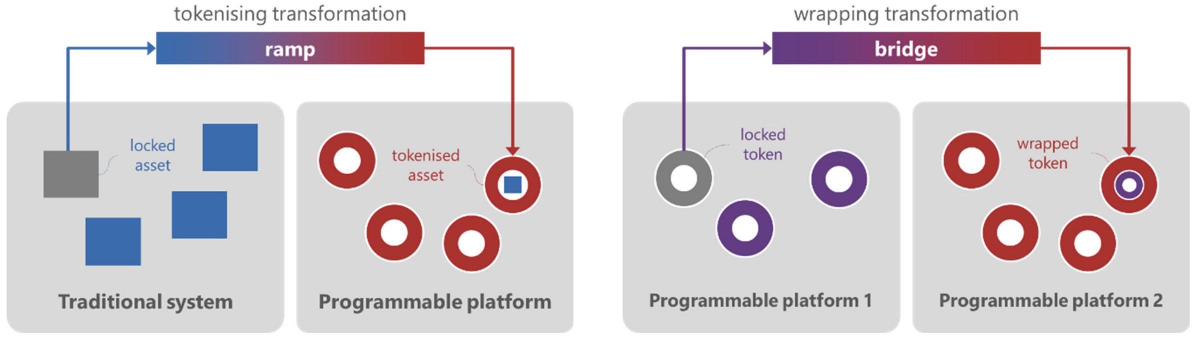
[4] An analogy to this computational transformation would be converting an Excel spreadsheet with a complex macro containing information on the shopping carts of all customers of a retail store into a mobile application that resides only on the smartphone of the customer.

owners of siloed proprietary databases (eg banks) to initiate the transfer. These databases often have different standards and are connected through third-party messaging systems, which can lead to delays and necessitate manual compliance checks. By tokenising money on a common programmable ledger, it becomes an executable object. Users can directly transfer their money without messaging an intermediary first, or let transactions be executed through smart contracts, which allows for automation and composability. Within their service layer, tokens could further embed compliance requirements that depend on eg the transacting parties, their location and the type of transfer.

Ramps and bridges are critical to linking different systems — Graph 3

A. Ramps link traditional and programmable platforms

B. Bridges connect programmable platforms



Source: Authors' elaboration.

A good example of the greater capabilities that tokenisation could enable is the mitigation of foreign exchange (FX) settlement risk, which affects a large portion of the multi-trillion dollar FX market. FX settlement risk refers to the risk that one party to a currency trade fails to deliver the currency owed. It is a form of counterparty risk involving both credit and liquidity risk. Netting and payment versus payment (PvP) mechanisms help to mitigate it, but existing PvP arrangements are at times unavailable, unsuitable for some trades or deemed too costly by market participants, so that risks remain (CPMI (2022)). Tokenisation could help overcome some of these barriers through near-instant atomic settlement around the clock. Smart contracts that combine currencies with authorised FX providers could facilitate the integration of more currencies on a common platform at lower cost, expanding the scope of PvP arrangements.

Another example of the potential for new types of transaction opened up by tokenisation is the market for securities. For example, mortgage-backed securities (MBS) pool mortgage loans into tranches of debt that are subsequently purchased by investors. Yet even in the deeply liquid $12 trillion US MBS market, the process of securitisation involves over a dozen intermediaries.[5] Automation through smart contracts could eliminate time lags in information and payment flows. Tokenisation could further reduce the need for intermediaries by, for example, integrating how borrower repayments are pooled and distributed to investors in a token's service layer through smart contracts. Faster transactions and fewer intermediaries could lower the cost of credit for households and broaden the investor base, thereby improving liquidity. More broadly, tokenisation could enable new contracting possibilities. For example, investors could buy government bonds that fund a green investment and – through smart contracts – link their accrued interest to the amount of clean energy that is generated.[6]

[5] For example, the so-called servicer collects borrower repayments, pools them and forwards them to a trustee. The trustee then distributes the pooled repayment to security holders according to the structure set in the transaction documents.

[6] See BIS Innovation Hub, Project Genesis.

These benefits notwithstanding, tokenisation is subject to economic, legal and technical challenges.

Economic frictions, in particular adverse selection and moral hazard, can impede tokenisation. These informational frictions are an intrinsic feature of many markets and explain the presence of intermediaries. For example, when a bank makes a loan to a non-financial firm, the borrower knows more about the quality of its project and the effort devoted to it. To ensure that funds are put to their intended use, lenders need to screen the quality of the borrowing firm ex ante and monitor performance ex post.

Claims that tokenisation will obviate intermediaries bypass the critical role intermediaries play in the face of contract-incompleteness. Intermediaries are often an endogenous response to economic frictions, rather than just the result of misguided legislation or undue market power. Technology alone cannot overcome these market imperfections, which suggests that intermediaries will continue to play a role in transactions involving tokenised assets (Aldasoro et al (2023)).

Tokenisation also faces significant legal challenges. Rules and regulations governing tokenised assets must be fully aligned with those of their real-world counterparts, which requires significant regulatory coordination to prevent unintended consequences such as shadow activities, theft and regulatory arbitrage. This task is easier for assets subject to legal frameworks and regulations that are fairly standardised and can be easily translated into a computer algorithm. However, even in such cases, additional complexities arise. For example, consider a mortgage-financed property: who would have the right to tokenise, and hence lock the property? To the extent that the lender has a legal claim on the property, tokenisation would likely require some coordination between the lender and the homeowner. Broader legal challenges include issues of investor and consumer protection, cyber security, and regulatory compliance across borders.

Technical challenges, particularly in the design of ramps, also loom large. Trading tokenised assets requires the original assets to be locked and unlocked in their traditional systems, which requires seamless interaction across systems. Integrating traditional systems with different application and database layers is already a tall order. Integrating them with programmable platforms faces additional hurdles. For example, to lock a property on a platform, the on-ramp would need to ensure that the property is no longer tradable in the real world. As property titles are kept in disparate local registries, full automation without the involvement of (offline) intermediaries is challenging. Generally, the feasibility of on-ramping, and associated benefits on the programmable platform, depend on the level of automation and harmonisation of the systems of origin.

Changes in token standards on a platform pose an additional challenge, as they would have to be reflected in the traditional ledger recording the original assets. For example, introducing the possibility of fractional ownership of tokens requires real-world systems to accommodate this possibility. To the extent that tokenisation offers novel ways of asset transfer and ownership that cannot be performed in traditional systems, the need for consistency across systems could limit the benefits of tokenisation.

The tokenisation continuum

The economic, legal and technical challenges define two ends of a "tokenisation continuum" for different financial and real assets (Graph 4).

On one end lie assets in systems that require frequent manual workflow procedures and are grounded on complex legal and regulatory frameworks, reflecting underlying economic frictions. These systems will start with less autonomous tokens, whose core and service layers will be relatively simple, and where tokenisation transformations – their ramps into programmable platforms – and de-tokenisation transformations – their ramps out of the platforms – will be more frequent. Examples could include syndicated loans or commercial real estate. Tokenisation will be considerably more challenging in such cases, despite the promise of large gains.

On the other end lie assets in digital, mostly automated systems with streamlined processes, and clear legal and regulatory frameworks. These assets will be more amenable to tokenisation, not least because they are better able to generate ramp standards for tokens to exist in programmable platforms. They would also require fewer tokenisation and de-tokenisation transformations. Transactions in these systems, however, are usually already relatively fast, cheap and convenient. This could limit the appeal of tokenisation to begin with, as gains may be smaller in areas where tokenisation is most straightforward.

The tokenisation continuum | Graph 4

Source: Authors' elaboration.

As modest gains in large volume markets can add up to significant amounts, one should not discard the aggregate benefits of tokenisation. Think of government securities. The trading of government bonds in electronic markets tends to be fairly standardised and is subject to negligible informational frictions. In a trillion-dollar market with high turnover, automated trading of securities on a common platform would yield sizeable benefits, even if the gains per trade are small.

Conclusion

Tokenisation could bring benefits through the automation of transactions and new ways of asset transfer, but it also poses economic, legal and technical challenges that are specific to the asset being tokenised. These challenges delineate a tokenisation continuum and highlight a trade-off: where tokenisation is easiest, per-unit gains are likely to be modest; but where tokenisation is difficult, the potential benefits are the largest. Efforts in the realm of tokenisation should therefore concentrate on identifying assets that are suitable for tokenisation and traded in large volumes.

References

Aldasoro, I, S Doerr and P Koo Wilkens (2023): "The economic limits to tokenisation", mimeo.

Bank for International Settlements (BIS) (2022): "The future monetary system", *Annual Economic Report,* June, Chapter 3.

Boissay F, G Cornelli, S Doerr and J Frost (2022): "Blockchain scalability and the fragmentation of crypto", *BIS Bulletin*, no 56, June.

Committee on Payments and Market Infrastructures (CPMI) (2022): "Facilitating increased adoption of payment versus payment (PvP)", Consultative Report, July.

Financial Stability Board (FSB) (2022): "Regulation, Supervision and Oversight of Crypto-Asset Activities and Markets: Consultative document", October.

Financial Stability Board (FSB) (2023): "The Financial Stability Risks of Decentralised Finance", February.

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

Previous issues in this series

No 71 29 March 2023	Fiscal and monetary policy in emerging markets: what are the risks and policy trade-offs?	Ana Aguilar, Carlos Cantú and Rafael Guerra
No 70 24 February 2023	Private debt, monetary policy tightening and aggregate demand	Miguel Ampudia, Fiorella De Fiore, Enisse Kharroubi and Cristina Manea
No 69 20 February 2023	Crypto shocks and retail losses	Giulio Cornelli, Sebastian Doerr, Jon Frost and Leonardo Gambacorta
No 68 7 February 2023	Why are central banks reporting losses? Does it matter?	Sarah Bell, Michael Chui, Tamara Gomes, Paul Moser-Boehm and Albert Pierres Tejada
No 67 26 January 2023	Does money growth help explain the recent inflation surge?	Claudio Borio, Boris Hofmann and Egon Zakrajšek
No 66 12 January 2023	Addressing the risks in crypto: laying out the options	Matteo Aquilina, Jon Frost and Andreas Schrimpf
No 65 16 December 2022	London as a financial centre since Brexit: evidence from the 2022 BIS Triennial Survey	Jakub Demski, Robert N McCauley and Patrick McGuire
No 64 13 December 2022	Energy markets: shock, economic fallout and policy response	Fernando Avalos, Adam Cap, Deniz Igan, Enisse Kharroubi and Gabriela Nodari
No 63 9 December 2022	"Front-loading" monetary tightening: pros and cons	Paolo Cavallino, Giulio Cornelli, Peter Hördahl and Egon Zakrajšek
No 62 1 November 2022	Global exchange rate adjustments: drivers, impacts and policy implications	Boris Hofmann, Aaron Mehrotra and Damiano Sandri
No 61 22 September 2022	Global supply chain disruptions: evolution, impact, outlook	Deniz Igan, Phurichai Rungcharoenkitkul and Koji Takahashi
No 60 16 September 2022	Inflation indicators amid high uncertainty	Fiorella De Fiore, Marco Lombardi and Daniel Rees
No 59 14 July 2022	Hard or soft landing	Frederic Boissay, Fiorella De Fiore and Enisse Kharroubi
No 58 16 June 2022	Miners as intermediaries: extractable value and market manipulation in crypto and DeFi	Raphael Auer, Jon Frost and Jose Maria Vidal Pastor
No 57 14 June 2022	DeFi lending: intermediation without information?	Sirio Aramonte, Sebastian Doerr, Wenqian Huang and Andreas Schrimpf

All issues are available on our website www.bis.org.