FSB FINANCIAL STABILITY BOARD

The Financial Stability Implications of Tokenisation

22 October 2024

The Financial Stability Board (FSB) coordinates at the international level the work of national financial authorities and international standard-setting bodies in order to develop and promote the implementation of effective regulatory, supervisory and other financial sector policies. Its mandate is set out in the FSB Charter, which governs the policymaking and related activities of the FSB. These activities, including any decisions reached in their context, shall not be binding or give rise to any legal rights or obligations.

Contact the Financial Stability Board

Sign up for e-mail alerts: www.fsb.org/emailalert
Follow the FSB on X/Twitter: @FinStbBoard
E-mail the FSB at: fsb@fsb.org

Table of Contents

Executive summary

For the purposes of this report, tokenisation refers to a process that involves utilising new technologies, such as distributed ledger technology (DLT), to issue or represent assets in digital forms known as tokens. These tokens may represent existing assets – including financial assets such as securities or bank deposits and physical assets such as real estate – or new assets that represent a claim against the issuer. The report focuses on tokenisation involving financial assets and does not cover certain other digital assets, including central bank digital currencies (CBDCs) and crypto-assets, which have been the subject of previous reports by the FSB or standard-setting bodies (SSBs).

The limited publicly available data on tokenisation suggest that its adoption is very low but appears to be growing. Tokens are currently used for trading, investment and, in a few cases, payments, but may have other uses in the future. Most of the recent investment has been in tokenisation projects that use DLT as the underlying technology platform. These projects, which include some collaborations between the public and private sectors, cover a range of use cases. They include using DLT to issue tokens that represent government debt or equity stakes in debt funds; creating DLT-based tokens to use for payments; and using DLT to tokenise pieces of gold.

The potential benefits of tokenisation may include improved efficiency, including in clearing and settlement, reduced costs, increased transparency, and greater flexibility, including expanded opportunities for investors. However, many of these benefits have yet to be proven, may not be uniquely achievable through tokenisation, and may involve trade-offs that might negate the benefits. As a result, tokenisation projects have not scaled significantly. Challenges for scaling up include unclear investor demand for these products; lack of interoperability among DLT platforms and between those DLT platforms and traditional financial infrastructure; the unavailability of money settlement assets; and differences in legal and regulatory frameworks, given the cross-border nature of many projects.

This report identifies several financial stability vulnerabilities associated with DLT-based tokenisation, which relate to liquidity and maturity mismatch; leverage; asset price and quality; interconnectedness; and operational fragilities. These vulnerabilities have been identified in the context of a number of constraints and assumptions, due to a lack of comprehensive data about the scale and activities of existing tokens and an understanding that tokenisation is rapidly evolving and its future state is unknown. In addition, there is a lack of information about how evolving forms of tokenisation fit into existing markets, legal and regulatory frameworks, and supervisory approaches that could address vulnerabilities.

The vulnerabilities of DLT-based tokenisation relate to three factors, individually and in combination: the underlying “reference asset” that has been tokenised; the participants in DLT-based tokenisation projects; and new technology as well as its interaction with legacy systems. Taken together, these factors can amplify many of the same vulnerabilities as in traditional finance, although they may play out differently depending on design choices, adoption, and scale of initiatives. For example, the choice of settlement assets (particularly tokenised private money) may amplify liquidity or other vulnerabilities; some of the entities involved in tokenisation are new entrants that may not be compliant with applicable laws and regulations or fall outside of the

regulatory remit in some jurisdictions; and DLT is an evolving technology that is relatively untested, which could create operational fragilities.

Notwithstanding these vulnerabilities, the use of tokenisation in the financial sector does not currently pose a material risk to financial stability, mostly due to its small scale. Additional factors that limit financial stability concerns include the current focus on permissioned (rather than permissionless) platforms, limited use of programmability features, and the lack of interoperability among DLT platforms and between DLT platforms and the financial sector. However, tokenisation could have implications for financial stability under certain conditions, including if the tokenised part of the financial system scales up significantly, if increased complexity and opacity of tokenisation projects lead to unpredictable outcomes in times of stress, and if some vulnerabilities are not adequately addressed through oversight, regulation, supervision, and enforcement.

In light of the findings in this report and the rapid evolution of the technologies that facilitate DLT-based tokenisation, the following are initial issues for the FSB, SSBs, and national authorities:

- Consider ways to address data and information gaps in monitoring tokenisation adoption. Authorities could assess these gaps and explore various sources of data and information including through reporting by regulated entities, information from market participants, and open-source data available on DLT platforms or other public information sources.

- Consider ways to increase understanding of how tokenisation and its related features fit into legal and regulatory frameworks and supervisory approaches, taking into consideration ongoing relevant work by SSBs and international organisations.

- Continue to facilitate cross-border regulatory and supervisory information sharing on tokenisation. The FSB working with SSBs could consider ways to facilitate information sharing, including monitoring developments across member jurisdictions.

1. Introduction

For the purposes of this report, the term "tokenisation" refers to a process that involves utilising new technologies, such as distributed ledger technology (DLT), to issue or represent assets in digital forms known as tokens. Any type of existing asset may be tokenised, including financial assets such as equities, fixed income securities, or bank deposits, or non-financial or physical assets. Some tokens are representations of existing assets, while other tokens are new assets representing a new claim against the issuer. These types of tokens are currently used for trading, investment and, in a few cases, payments purposes, but may have other uses in the future.

Tokenisation may have the potential to offer benefits to the financial system, such as increased efficiency and transparency in some cases, but it may also have financial stability implications. While the size of the market for tokenised assets remains relatively small, and it is unclear how tokenisation will evolve and which models will gain traction, a growing number of financial and non-financial institutions are initiating or taking part in tokenisation projects. These efforts, along with the ongoing evolution of the technologies that facilitate tokenisation, underpin this report's examination of the potential financial stability implications of tokenisation, should it scale.

The analysis draws from publicly available information related to public and private sector tokenisation initiatives, a review of existing literature, studies of some tokenisation projects currently operating in the market, and engagement with relevant stakeholders. Given that tokenisation initiatives vary widely across jurisdictions, the analysis is based on observations from tokenisation initiatives that cover different types of assets; domestic and cross-border uses; and public and private sector led initiatives.

The report is focused on a subset of tokenisation initiatives – tokenisation based on DLT as the underlying technology platform[1] – assessed to be the most relevant for financial stability based on recent market developments. In particular, the report focuses on the tokenisation of financial assets, such as tokenised money that may potentially be used as a settlement asset for payments (e.g. commercial bank deposits and existing forms of wholesale central bank money, namely central bank deposits that are used for interbank settlement)[2] and other financial assets (e.g. securities such as mutual fund shares).[3] The report does not examine initiatives involving central bank digital currencies (CBDCs) or crypto-assets.

This report analyses recent developments in DLT-based tokenisation, including the potential uses of tokenised assets and their interaction with the traditional financial system, and identifies financial stability vulnerabilities related to tokenisation. In order to form a comprehensive view of these vulnerabilities, tokenisation was reviewed from two analytical perspectives: (i) the key features of DLT-based tokenisation and the extent to which those features, alone or in

---

1 "DLT platform" is used throughout the report to describe the platform used, not only to issue tokens as a part of the tokenisation process, but also to enable financial activities (e.g. trading) involving the token.

2 Financial settlement assets may include stablecoins, which are also used for various other purposes. While stablecoins are relevant for tokenised markets as they could be used for settlement of transactions on the blockchain, the FSB has explored the financial stability implications of stablecoins in other reports so stablecoins are not extensively examined in this report.

3 The tokenisation of non-financial and physical assets, such as real estate or gold, has been considered in the preparation of this report but this is not currently widely observed in the market and has not been a key focus area for financial stability. In addition, while it is possible for crypto-assets like Bitcoin or Ether to be used in programmable platforms underpinning tokenised systems as "wrapped" tokens for trading on different platforms, this has not been observed in regulated markets. As a result, the potential financial stability vulnerabilities of this type of token have not been analysed in this report.

combination, create or amplify vulnerabilities; and (ii) the vulnerabilities identified in the FSB financial stability surveillance framework.[4] The key vulnerabilities relate to (i) the characteristics of the underlying reference asset that has been tokenised; (ii) the participants in the project; and (iii) new technology as well as its interaction with legacy systems. These factors, individually and in combination, can amplify many of the same vulnerabilities as in traditional finance, although they may play out differently depending on design choices, adoption, and the scale of the initiatives.

The report further evaluates the conditions under which tokenisation may present a material financial risk for the wider financial system, identifies information gaps and areas for further monitoring, and presents policy issues for consideration.

The report is structured as follows:

- Section 2 describes the tokenisation landscape, including definitions and common features, the current status of adoption and use of tokenised assets in the financial system, the potential benefits, and reasons why there has not been broader adoption.[5]
- Section 3 examines the potential financial stability vulnerabilities of tokenisation in terms of liquidity and maturity mismatch; leverage; asset price and quality; interconnectedness, including complexity; and operational fragilities.
- Section 4 reviews the financial stability implications of the identified vulnerabilities. This section examines which conditions may create a material financial stability risk should tokenisation markets grow in size and would accordingly warrant monitoring.
- Section 5 discusses conclusions from the analysis and considerations for the FSB and relevant SSBs.

2. Background on tokenisation

2.1. Definitions

Tokenisation in the context of this report refers to the issuance or representation of assets in the form of digital tokens using technologies such as distributed ledgers. The tokens considered in the report are of two types: (i) tokens that are issued solely or directly on DLT (sometimes referred to as “native” tokens); and (ii) tokens that are digital representations of physical assets or existing assets that were originally issued elsewhere (sometimes referred to as “non-native” tokens). These two types are discussed in subsection 2.2. Theoretically, any type of asset can be used as a reference asset for non-native tokens, including assets that may be used for settlement, non-settlement financial assets, and non-financial or physical assets (see Table 1 below). This report focuses mainly on tokenisation initiatives involving financial assets because

4 FSB (2021), *FSB Financial Stability Surveillance Framework*, September.

5 The discussion in this report should not be taken to constitute any claim about compliance with existing laws and regulations in relevant jurisdictions of specific tokens, their issuers, or other individuals or entities. Individual jurisdictions might have different legal interpretations for terms used in this report and different assessments of the compliance of individuals, entities, products, or services with regulations relevant to these jurisdictions.

they are most relevant for financial stability. In addition, in this report, "tokens" generally refers to both directly issued tokens and digital representations of pre-existing assets as they present similar financial stability vulnerabilities, albeit with a few exceptions, which are explicitly noted. This report does not cover CBDCs or crypto-assets (or their representation on other blockchains through so-called wrapped tokens)[6] as these have been the subject of separate analyses by the FSB and SSBs, and therefore fall outside the scope of this report.

Table 1: Examples of reference assets covered in the report

Reference asset	Examples of reference asset	Description[7]
Settlement asset	Commercial bank money	Tokenised deposits
	Other privately issued money	Stablecoins that are used for settlement
Non-settlement financial asset	Money market fund (MMF)	Tokens representing a claim on a money market fund investing in financial assets such as Treasury bills
	Corporate equity/bond	Tokens representing a corporate equity/bond on DLT
	Real estate investment trust (REIT)	Tokens representing a claim on a real estate investment trust
Non-financial (physical) assets	Real estate	Token representing a fractional share of a financial interest in property
	Gold	Token representing a fractional share of the physical commodity (as opposed to a fund based on the commodity)

Tokenisation has no generally accepted definition, including among those in the financial industry, and the term has not been used in a standardised way in connection with various initiatives. The terminology used by public and private sector organisations in reports and initiatives related to tokenisation is not always consistent (see Box 1 for examples of different definitions used by international organisations and SSBs). Some definitions focus on the underlying technology, while others consider the features of tokenisation, the types of assets tokenised, and the linkages, if any, between reference assets and digital tokens.

Some aspects of tokenisation resemble other existing digital representations of assets and activities in the financial system. For example, both tokenisation and securitisation can allow investors to receive a fraction of cash flow based on an underlying asset, known as asset fractionalisation.[8] Fractionalisation allows assets to be divided up into smaller shares, making them potentially more accessible to investors. On the other hand, there are differences including

6 A "wrapped" token is a crypto-asset that is created on a blockchain as a synthetic for a given token on another blockchain, effectively serving as a bridge between one blockchain and another. See International Organization of Securities Commissions (IOSCO) (2022), *IOSCO Decentralized Finance Report*, March.

7 As there are no universally agreed definitions for some of the terminology, there could be different descriptions of the reference assets depending on the context. The description in this table is solely for the purpose of this report.

8 Securitisation is a structured finance tool that involves the actual (also known as cash or true sale) or synthetic transfer of assets or risk exposure with the aim of achieving risk transfer or providing funding. See FSB (2024), *Evaluation of the Effects of the G20 Financial Regulatory Reforms on Securitisation: Consultation report*, July.

those stemming from the use of DLT. For example, DLT may allow for the possibility to program the use of tokens in ways that may be technologically different from those in the traditional financial system, as discussed below.

Box 1: Examples of definitions of tokenisation by international organisations and SSBs

- The Committee on Payments and Market Infrastructures (CPMI) and the Bank for International Settlements (BIS) define tokenisation as the process of generating and recording a digital representation of traditional assets on a programmable platform.[9]
- The Organisation for Economic Co-Operation and Development (OECD) describes tokenisation as "the digital representation of pre-existing real assets on distributed ledgers by linking or embedding by convention the economic value and rights derived from these assets into digital tokens created on the blockchain; or the issuance of traditional asset classes in tokenised form on distributed ledgers." The OECD further distinguishes between tokenised assets issued on the back of real assets that exist "off the blockchain" (so-called digital twins) and so-called "native tokens", also called "coins", which are "built directly on-chain and live exclusively on the distributed ledger." The OECD states that native tokens "derive their value in and of themselves and are defined by their existence on the blockchain."[10]
- In the context of discussing the implications of digitalisation on banking, the Basel Committee on Banking Supervision (BCBS) has described tokenisation as "the process of representing claims digitally on a programmable platform."[11]
- In the context of discussing DLT and the role of tokenisation of assets and fiat money, the International Organization of Securities Commissions (IOSCO) defines tokenisation as "the process of digitally representing an asset or ownership of an asset. A token represents an asset or ownership of an asset. Such assets can be currencies, commodities, securities or properties."[12]

2.2. DLT-based tokenisation and its key features

This report focuses on DLT-based tokenisation as this is the technology underpinning most private and public sector tokenisation projects to date. DLT refers to the protocols and supporting infrastructure, including blockchains,[13] that provide a means of recording information on a ledger that can be distributed or shared by multiple parties.[14] The infrastructure contains the data on the ledger, and the protocols are key to determining the behaviour of the shared ledger. DLT allows for the possibility of multiple parties in a network, which are referred to as "nodes", to "propose, validate, and record changes (updates) consistently across the network."[15]

One of the features of DLT systems that may allow for different roles and arrangements to those in traditional systems is the use of consensus mechanisms to achieve agreement among

---

9 BIS-CPMI (2024), *Tokenisation in the context of money and other assets: concepts and implications for central banks*, October.

10 OECD (2020), *The Tokenisation of Assets and Potential Implications for Financial Markets*, March.

11 BCBS (2024), *Digitalisation of finance*, May.

12 IOSCO (2017), *IOSCO Research Report on Financial Technologies (Fintech)*, February.

13 Blockchain is one form of DLT in which details of transactions are held in a data structure that consists of blocks of information. A block of new information is appended to a tamper-proof chain of pre-existing blocks that are linked together using a cryptographic mechanism. See FSB (2023a), *The Financial Stability Risks of Decentralised Finance*, February.

14 Bech and Garratt (2017), Central bank cryptocurrencies, *BIS Quarterly Review*, September; and FSB (2019), *Decentralised financial technologies: Report on financial stability, regulatory and governance implications*, June.

15 FSB (2019).

network participants on the state of the ledger. Consensus mechanisms can reduce the need for a single central party to perform record-keeping on the ledger. Consensus is achieved through protocols, i.e. pre-agreed rules, which allows participants to update the ledger. When tokens are issued on a DLT platform, data are stored on the infrastructure (i.e. the ledger), and can include information related to the asset type, ownership details, and asset valuation, among other elements. While such functionality can potentially reduce the reliance on or change the roles of intermediaries, some functions associated with tokenised markets still need to be provided by third parties. Custody and redemption of tokens that are issued on a DLT are services that may require third party service providers. For instance, reference assets that are tokenised may need to be placed in physical custody (e.g. commodities such as gold).[16]

There are several key features of DLT-based tokenisation that are relevant for financial stability.

- **Governance**. Access to read, write, and determine what information is added to the ledger varies depending on the governance framework of a particular DLT platform and falls into two general categories: "permissioned" or "permissionless." In permissioned DLT, participants are approved by a coordinating body (such as a financial or governmental institution), whereas permissionless DLT may allow anyone to participate with equal permissions and participants' true identities may be unknown. However, it is important to note that there is a great degree of variation and flexibility in the design and rules within these governance models, and permissioned and permissionless platforms may sometimes share common traits. For example, while permissioned DLT platforms may have a central authority that controls access, this authority may distribute governance authority across multiple parties (e.g. several parties may contribute to decision-making). In practice, permissionless DLT platforms are very often dominated by a few players. Thus, the distinction between permissioned and permissionless can be blurred. As described below, design choices for DLT platforms and the resulting degree of access control may affect issues such as platforms' operational capacity, security, and risk management, which may have ramifications for financial stability.

- **Programmability and composability**. Programmability refers to a feature of certain DLT platforms that allows eligible participants to write and deploy computer code onto the platform to create specific rules that will execute automatically in response to pre-determined triggering conditions or data. These pieces of code that execute when certain conditions are met are referred to as "smart contracts." Smart contracts can be responsible for both the issuance and programmability of the token itself as well as usage of the token on the platform. Programmability on DLT platforms is relevant for financial stability because of its potential to change how financial market functions are performed by, for example, increasing automation. Programmability enables the creation of products that combine features and functionalities in new ways, known as composability in the DLT context. For example, composability may allow for tokens to be automatically spent or used by other programmable components on the platform. Composability may also allow for the creation of tokens that can facilitate a variety of activities, potentially enabling users to engage in complex and opaque transactions.[17]

16 OECD (2020).

17 FSB (2023a).

Composability is relevant for financial stability since it creates interdependencies that generate interconnectedness that may be hidden or hard to track.

- **Type of issuance**. As noted above (see subsection 2.1), tokens could be: (i) issued solely or directly on DLT; or (ii) digital representations of physical assets or existing assets that were originally issued elsewhere.[18] For example, in the former case, an issuer may use the platform to issue the token and the economic value of the token may arise from the operations of the issuer, such as with equity, or may represent a debt obligation of the issuer. In the latter case, the token issuer may sell a fractionalized, undivided interest in a real asset, with the token issuer being the record owner of that asset. Both types of issuances have characteristics that are relevant for financial stability. For example, a token's linkage to a reference asset means that there is a possibility of misalignment of the prices of the token and the value of the reference asset, and different risks may arise depending on the type of reference asset, including in relation to their storage and valuation.[19] By contrast, tokens that do not have a linkage to a reference asset are still subject to issuer risks, including regarding the soundness of the token issuer.

- **Choice of settlement asset.** Some of the potential benefits of tokenisation are related to the possibility for trades, asset settlement and money settlement to take place on the same or across fully interoperable DLT platforms. Existing tokenisation initiatives are exploring a variety of settlement assets for the payment leg(s) of transactions, including CBDCs and tokenised private money such as stablecoins or tokenised bank deposits. The financial stability implications may differ depending on the type of settlement asset used on DLT platforms and its design. For tokenisation initiatives to sufficiently scale within regulated financial markets, the settlement asset would need to comply with proper regulation, supervision, and oversight, and, as applicable, to meet minimum risk management standards consistent with the CPMI-IOSCO Principles for Financial Market Infrastructures (PFMI).[20]

- **Reliance on third parties**. Since not all of the functions – issuance, trading, investment, and payments/settlements – can be performed on DLT, tokenisation may require the involvement of third parties. The types of third-party activities may depend on the token characteristics. For example, non-native tokens involving an existing asset may need "custodians" to safekeep reference assets; "oracles" to collect data and store it on DLT platforms such that the data can be used by smart contracts;[21] and "ramps" to facilitate the exchange of assets in traditional financial structures with assets on DLT platforms.[22]

---

18 What falls within the scope of a tokenised asset could vary depending on jurisdictional frameworks. For banks, the BCBS prudential treatment of crypto-asset exposures includes a definition of what constitutes a tokenised traditional asset for the purposes of the prudential treatment.

19 Ocampo et al. (2023), Crypto, tokens and DeFi: navigating the regulatory landscape, FSI Insights No. 49, May.

20 The PFMI contains a principle addressing money settlements, stating that financial market infrastructures (FMIs) should conduct money settlements in central bank money, where practical and available, to avoid exposing the FMI or its participants to credit and liquidity risk. If central bank money is not used, an FMI should conduct money settlements using a settlement asset with little or no credit or liquidity risk. An FMI that conducts money settlements on its own books should minimize and strictly control credit and liquidity risks. Systemically important FMIs may potentially observe the PFMI by settling in central bank money, settling payments on their own books, or using commercial bank money. In all cases, rigorous risk management is required. See Principle 9 of CPMI-IOSCO (2012), *Principles for financial market infrastructures*, April.

21 Duley et al. (2023), *The oracle problem and the future of DeFi*, BIS Bulletin No. 76, September.

22 Aldasoro et al. (2023), *The tokenisation continuum*, BIS Bulletin No. 72, April.

Other kinds of third parties, such as developers and maintainers of "bridges",[23] help with the exchange of tokens on one DLT platform with tokens on another. The third-party service providers involved in DLT-based tokenisation are relevant for financial stability because the functions they perform, and the quality of the performance, may affect many aspects of platform functioning and token valuation.[24]

2.3. Adoption and use in the financial system

The tokenisation of assets on DLT is relatively nascent, and there are no examples of a tokenisation project that has scaled significantly. Most tokenisation projects are still at the proof-of-concept stage. The tokens already in production are generally limited to transactions between a limited set of known parties or within a small, closed loop network. The FSB reviewed several tokenisation initiatives that involve: (i) different types of assets, including financial assets[25] and settlement assets (see Table 1 for examples);[26] (ii) projects at the domestic and global levels; (iii) the use of DLT with different types of governance models; and (iv) both public and private initiatives, including examples of public-private collaboration.[27] These projects mostly involved traditional financial intermediaries but other firms were also involved in a few cases.

The limited publicly available data on tokenisation suggest that its adoption is very low but appears to be growing. There is a lack of comprehensive and consistent data related to tokenisation, including the market share of various types of tokens and reference assets, the pace of growth in the market, and the overall size of the market. This is due in part to the differing definitions of tokenisation as well as the wide variety of tokenisation models and assets that can be tokenised. Many tokenisation initiatives are nascent and/or projects of private sector firms within their own books and records. Additionally, there is a lack of transparency in some DLT-based tokens, stemming from a lack of reporting and disclosure requirements and/or a lack of compliance with applicable reporting requirements related to DLT-based financial instruments in some jurisdictions. These limitations mean that it is not possible to present a comprehensive picture of the total current tokenisation activities. One analysis of tokenised assets on public, permissionless blockchains in May 2023 estimated that the total market value of those tokens was $2.15 billion.[28] Industry estimates of potential growth and the speed of adoption of tokenised assets vary widely and are not well-substantiated, although there are some preliminary

---

23 Bridges are protocols that issue representations of assets on different, otherwise incompatible DLT platforms. See FSB (2023a).

24 These ancillary services are not always provided by third parties, they may be provided by the platform owner.

25 An example is European Investment Bank (EIB) sovereign bonds, which are issued as digital bonds on permissioned and permissionless DLT platforms. The aim, according to EIB, is reducing costs, improving efficiency, and allowing for real-time data synchronisation across participants. See EIB (2021), EIB issues its first ever digital bond on a public blockchain, April; EIB (2022) EIB innovates further with Project Venus, the first euro-denominated digital bond on a private blockchain, November.

26 An example is the JPM Coin, which implemented a payment rail aimed at streamlining financial services with a commercial bank settlement asset for customers of J.P. Morgan, including customers that are financial intermediaries participating in the arrangement. The payment rail aims to provide instant settlement and improved liquidity for various financial services, according to JPMC. See Onyx Coin Systems by J.P.Morgan.

27 An example is Project Guardian, an initiative of the Monetary Authority of Singapore (MAS) to foster collaboration between international policymakers and the financial industry to test the feasibility of applications in asset tokenisation while managing risks to financial stability and integrity. Asset tokenisation is examined across financial asset classes such as asset and wealth management, fixed income, and foreign exchange -- and using permissioned and permissionless DLT platforms. See Project Guardian. For additional information about public sector tokenisation projects, see BIS-CPMI (2024).

28 Carapella et al. (2023), *Tokenization: Overview and Financial Stability Implications* , *Finance and Economics Discussion Series*, Federal Reserve Board, December.

observations that the pace of growth may be accelerated for certain types of tokenised assets.[29] The market value of tokenised money market products, including MMFs holding US Treasuries, roughly doubled from May 2023 to May 2024 to more than US$1 billion outstanding on permissionless blockchains.[30]

Many of the tokenisation initiatives examined aim to improve efficiency in clearing and settlement. These initiatives are testing the use of DLT-based tokenisation in the clearing and settlement process involving both central bank money and commercial bank money. Key potential use cases under examination are payments, payment versus payment (PvP) settlement and delivery versus payment (DvP) settlement.[31] Other initiatives explored the use of DLT for the issuance, underwriting, and trading of securities. For example, one project tokenised shares of real estate investment trusts. Some of the projects involving crypto-asset service providers have sought to address interoperability challenges in tokenisation by facilitating transactions between DLT platforms and the traditional payment system, and between different DLT platforms. As such, these projects mainly focused on enabling traditional financial activities with a new technology rather than fostering entirely new activities.

The majority of the initiatives by traditional financial institutions that were analysed for this report involve the issuance of tokens on permissioned platforms. Some opted to integrate current traditional systems with public permissionless blockchains, whereas other initiatives relied on newly developed platforms run by traditional actors or on proprietary standards. The tokenisation initiatives by crypto-asset service providers were more likely to launch on permissionless blockchain networks and selectively integrate with certain decentralised finance (DeFi) protocols.

2.4. Potential benefits of tokenisation

Sponsors of tokenisation initiatives argue that DLT-based tokenisation has the potential to deliver certain benefits. These generally involve creating efficiencies in the financial system and supporting the expansion in availability of financial products and services.[32] They include:

- Exchange-of-value ("atomic settlement"). Atomic settlement is a term commonly used in the context of DLT and refers to final settlement of two linked obligations where one leg of the transaction settles if and only if the other leg settles. While these settlement mechanisms exist today, some tokenisation initiatives are exploring how such settlement mechanisms could be facilitated by DLT.[33] DLT platforms could be programmed to allow multi-asset transactions to settle simultaneously if relevant conditions for payments or trades are satisfied. This may reduce the duration for which

---

29 Roland Berger (2023), *Tokenization of Real-World Assets: Unlocking a New Era of Ownership, Trading, and Investment*, October.

30 See the RWA.xyz webpage on Tokenized Treasuries. It should be noted that it is the shares of the fund itself that are being tokenised, and not the assets (such as Treasuries) in which the fund predominantly invests.

31 DvP (and PvP) can involve simultaneous and/or instantaneous transactions but does not explicitly mean either or both. Exchange-of-value settlements, such as DvP and PvP, eliminate principal counterparty risk in settlement through the condition that final settlement of the delivery of an asset occurs if and only if final settlement of the corresponding payment occurs. This conditionality is often operationally executed with simultaneous transactions, but simultaneity is neither necessary nor sufficient to ensure DvP.

32 Carapella et al. (2023).

33 Lee et al. (2022), *What Is Atomic Settlement?*, Federal Reserve Bank of New York Liberty Street Economics, November.

collateral is encumbered, which could reduce counterparty and settlement risk. However, atomic settlement may also substantially increase liquidity demands and risks in the system, in the absence of liquidity savings mechanisms.

- Improved efficiency and cost savings. Programmability could improve efficiency through automation by enabling the consolidation of trade and post-trade functions, which can create more efficient post-trade processes, reduce settlement risk, and reduce the need for intermediaries (e.g. escrow service providers).

- Greater flexibility and expanded opportunities for investors. Tokenisation could allow investors to access a wider range of investment opportunities, because it may facilitate greater fractional ownership of underlying assets.[34] Proponents argue that ease of investor access to opportunities may also increase due to the use of digital channels for tokens and the 24/7 availability of those channels. Proponents also say that composability of DLT-based tokenisation could open up possibilities for new financial products and services that may benefit investors. This could include new utilities of existing assets, for example by removing some of the operational barriers to using certain asset classes as collateral.

- Increased transparency in recordkeeping. DLT-based tokenisation could potentially improve the availability of auditable records of transactions and ownership and reduce reconciliation needs.[35] If tokenisation supports streamlined internal processes at firms or reduces the number of intermediaries involved in a transaction, it could potentially result in cost savings for firms and investors.

However, many of the purported benefits of tokenisation have yet to be fully proven, may not be uniquely achievable through tokenisation, and may involve trade-offs that might negate the benefits. For example, as discussed above, existing fractionalisation mechanisms (e.g. securitisation) already facilitate investor access to a range of assets. Tokenisation could reduce counterparty risk through atomic settlement but may increase liquidity demands on market participants, as discussed in Section 3. Some claims of benefits (e.g. fungibility of tokens and reference assets) may also not be consistent with prevailing legal and regulatory frameworks.

The potential relative gains of tokenisation depend on the scale of adoption across financial markets and asset classes. Some asset classes that stand to gain the most are also the more challenging to tokenise. These asset classes include those that are less standardised and that require frequent, manual processes (such as securitised products and private equity) and which entail complexity, including but not limited to legal requirements and multiple layers of intermediation. Such asset classes may involve more frequent tokenisation and de-tokenisation transformations, which, would be considerably more challenging, despite the larger promise of automation gains. In asset classes that already have digitised systems and processes, and clear frameworks (e.g. equities), the gains from tokenisation may be smaller and the value proposition is therefore less clear.[36] The high efficiency of some markets today, combined with some limitations of DLT (see below), suggest that, in the long run, there could be a mix of traditional

---

34 Carapella et al. (2023).

35 The Investment Association (2023), *Tokenised Funds -- Operational and cost differences*, March.

36 Aldasoro et al. (2023).

and DLT systems. The latter may be focused on asset classes for which the cost-benefit trade-off for tokenisation is most clear.

2.5. Key challenges for scaling tokenisation

Tokenisation could become relevant for financial stability if it scales considerably, but a number of factors limit its broader adoption in the financial system at present. These factors may be categorised into four broad categories: market-related conditions, interoperability challenges, multi-asset transaction considerations, and legal and regulatory challenges.

Although there has been industry interest in tokenisation, the extent of investor and other market participants' demand for these products remains unclear. Some of the purported benefits of tokenisation could be achieved in existing systems today but may not be implemented due to economic, policy, or market-related constraints, among other reasons. For example, fractionalisation of assets may be achieved through securitisation. The type of DLT platform underlying the tokenised asset may also create specific economic constraints. Permissioned DLT platforms may limit the development of deep and liquid secondary markets that are conducive to investments, due in part to constraints on participants that are part of the platform. Permissionless platforms have been unattractive for regulated financial institutions. One of purported reasons is because they do not currently support high-frequency transactions (e.g. it takes time to validate transactions on all relevant nodes).[37] In addition, there are challenges complying with anti-money laundering and countering the financing of terrorism (AML/CFT) requirements due to the pseudo-anonymity of users, wherein users may employ an alias or pseudonym as their digital identity, as well as the difficulties of meeting other regulatory and supervisory requirements.[38]

Transition costs and potential operational risks for market participants linked to moving from traditional infrastructures to DLT reduce business incentives, especially for financial institutions. Market participants report that DLT systems for tokenisation would need to run in parallel to existing systems, at least in the initial phase, which would greatly increase the initial costs of using DLT. In addition, the transition means having to manage two environments with different windows of operation and potentially fragmented liquidity across the tokenised and reference asset markets. The operational risks of transitioning to DLT may also include the potential instability of networks when used at scale and the higher potential for cyber-attacks in comparison with traditional infrastructures. To the extent that a DLT platform's governance structure creates more entry points, it could also create greater opportunities for attacks.

A lack of interoperability among DLT platforms and between those platforms and traditional financial infrastructure is another obstacle to scaling tokenisation. Many of the DLT platforms cannot transmit and share data with each other, thereby limiting their potential applications and benefits. There is currently a lack of tested market infrastructure to establish interoperability

---

37 Aldasoro et al. (2023).

38 The BCBS has concluded that the use of permissionless blockchains gives rise to a number of unique risks, some of which cannot be sufficiently mitigated at present. While technical solutions to many of these issues may develop in the future, at this time the BCBS has not proposed any adjustments to its crypto-assets prudential standard to allow for the inclusion of crypto-assets that use permissionless blockchains in Group 1. See BCBS (2024), *Cryptoasset standard amendments*, July; and BCBS (2024), *Novel risks, mitigants and uncertainties with permissionless distributed ledger technologies*, August.

between platforms and there are significant challenges to the development of the necessary components for such infrastructure.[39] One suggested solution is to develop multilateral or shared DLT platforms that aggregate siloed activities, which could serve as "common venues" to enable different transactions involving tokens.[40] However, such platforms would involve significant costs to develop, substantial coordination among stakeholders to harmonise standards and procedures for transacting across a shared ledger, as well as potential policy changes for jurisdictions participating in them.[41] Additionally, tokenising conventionally issued assets still fundamentally depends on connections to and communications with traditional infrastructure and the involvement of parties that do not operate 24/7/365. This limits the scope of such initiatives.

Many of the purported benefits of tokenisation depend on having settlement assets (e.g. central bank money, commercial bank money or new private forms of money such as stablecoins) on the same DLT platform or fully interoperable DLT platforms, which do not exist for many tokenised assets currently.[42] In order to operate, securities settlement systems either link to or incorporate payment systems. Transfer of other assets needs to be linked to payment. Some potential benefits of tokenisation are contingent on trading and post-trade processes, including settlement, taking place on the same platform or within interoperable systems. Expansion of asset tokenisation, particularly in support of payments, requires money settlement assets and/or combined transfer mechanisms to be available.

Compliance with different legal and regulatory frameworks may affect the scaling of tokenisation, given the cross-border nature of many projects. Authorities have taken different legal and regulatory approaches to asset tokenisation. Relevant considerations include whether existing regulations are applicable to asset tokenisation on DLT platforms and address potential vulnerabilities that may stem from tokenisation. In addition, claims that token holders have on issuers or underlying assets may lack legal clarity and may not be legally enforceable in some jurisdictions.[43] In some jurisdictions, the use of DLT also introduces a novel form of record-keeping that may entail new practices not contemplated by current regulations or not yet determined to be compliant with such regulations. Initiatives that aim to broadly restructure intermediation practices will, for example, necessarily interact with regulations addressing existing market practices. These may include mandatory clearing rules, and market integrity and efficiency roles played by central securities depositories (CSDs) in a given jurisdiction.[44]

---

39 Bank of America (2023), *Beyond Crypto: Tokenization*, July.

40 An example is a class of cross-border payment and contracting platforms which offer a trusted single ledger on which standardised digital representations of central bank reserves in any currency can be exchanged efficiently and programmed to replicate basic financial contracts in privacy-preserving manner, among selected public and private sector entities subject to a common set of governance, standards and rules. See Adrian and Mancini Griffoli (2023), *The Rise of Payment and Contracting Platforms*, *IMF Fintech Notes, No. 5*, June.

41 BIS (2023) "Blueprint for the future monetary system: improving the old, enabling the new", *Annual Economic Report 2023*, June, Chapter III.

42 McKinsey (2023), *Tokenization: A digital-asset déjà vu*, August.

43 OECD (2020); OECD (2021), Regulatory Approaches to the Tokenisation of Assets, March; and OECD (2021), "Understanding the tokenisation of assets in financial markets"*, OECD Going Digital Toolkit Notes*, November.

44 See Principle 11 (PFMI 11) in the CPMI-IOSCO (2012) for a discussion of the roles that CSDs may play in securities markets.

3. Vulnerabilities associated with tokenisation

The financial stability vulnerabilities arising from DLT-based tokenisation are based on those described in the FSB Financial Stability Surveillance Framework and relate to (i) liquidity and maturity mismatch; (ii) leverage; (iii) asset price and quality; (iv) interconnectedness; and (v) operational fragilities.[45] These vulnerabilities have been identified in the context of a number of constraints and assumptions, including a lack of comprehensive data about the scale and activities of existing tokens and an understanding that tokenisation is rapidly evolving and its future state is unknown. The vulnerabilities relate to three factors, individually and in combination: the underlying "reference asset" that has been tokenised; the participants in DLT-based tokenisation; and new technology as well as its interactions with legacy systems. Taken together, these factors may amplify many of the same vulnerabilities that exist in traditional finance. The factors also may play out differently depending on design choices, adoption, and scale of the initiatives, as well as the ability to address vulnerabilities through regulatory and supervisory changes, where applicable.

3.1. Liquidity and maturity mismatch

Tokenisation may introduce the potential for liquidity and maturity mismatch between the tokens and underlying assets. Such a mismatch can arise when the asset represented by a token and the token itself have different characteristics regarding convertibility into cash (liquidity) and settlement timelines (maturity of cash flows). Similarly, if a tokenised representation of an existing asset is perceived or treated as though it is more liquid than the asset it represents or references, the relative difference or the perception thereof may not be consistent over time. For example, a tokenised asset may offer its holders an opportunity to redeem its value at any time. However, if the assets backing this claim (e.g. reserve assets or a general claim) have a different maturity or liquidity profile than the token, this might increase redemption run risk, which could also trigger a liquidation of the underlying reference asset, with possible adverse spillovers to other parts of the financial system. The risk of runs due to liquidity and maturity mismatch is well-known in banking as well as in non-bank financial intermediation and is a key reason for regulatory requirements for certain types of financial entities. Some tokenisation initiatives are specifically attempting to address aspects of current mismatches, aiming to create a tokenised product that is less prone to run risk than its original reference product. It is too early to tell whether they can successfully serve this function or if they will simply replicate existing risk or create new ones.

Tokenisation enabling fractionalisation could also raise maturity and liquidity transformation issues similar to those encountered with collective investment schemes. For example, a token representing a share of an asset could give a false impression of ample market liquidity through marketing efforts, even though the reference asset is not liquid. A significant spike in redemption demands on the token in times of stress could force the issuer to sell the reference assets in less liquid markets, which could, in turn, trigger a downward price spiral on the tokens.

[45] FSB (2021).

Under certain circumstances tokenisation could reduce the availability of market participants' liquidity on-hand and erode their resilience to liquidity shocks. Many tokenisation projects aim to achieve fast settlement through mechanisms that eliminate principal counterparty risk but require high levels of liquidity, often through prefunding on a platform, since they settle on a gross basis (i.e. trade by trade). If such mechanisms are used at scale, this could lead to financial stability risks insofar as higher prefunding needs could weaken the ability of market participants to address liquidity shocks. Tokenisation initiatives seeking solutions to address these funding issues are still nascent. Nonetheless, even if they are successful and scale during normal conditions, there is a risk that market participants will operate under an untested assumption that funding will always be available when needed. This could lead such participants to keep insufficient liquidity on-hand, making them vulnerable to liquidity stress events.[46]

Liquidity pressures could also spread faster and wider through programmability and automation. Programmability features of smart contracts can allow for automatic liquidation systems to be put in place, similar to when margin calls get triggered in an automated fashion (potentially involving external price feeds by oracles or other intermediaries). When utilising tokenised assets in financial contracts (for example, if pledged as collateral), such features could trigger the automatic liquidation of any positions that become under-collateralised and could have an impact on the underlying reference assets, possibly causing runs on reference asset markets. Such runs might be intensified if they happen when the reference asset markets are closed while trading of the token is still active (e.g. over a weekend). These runs may also result in deviations of the value of the tokenised asset from the value of the reference asset, with subsequent possible losses for tokenised asset holders and their solvency.

As noted above, the choice of settlement asset in DLT-based tokenisation may have financial stability implications, since it may amplify liquidity mismatch, asset price and quality, and interconnectedness vulnerabilities. For example, this applies to tokenised private money such as stablecoins or tokenised bank deposits. Vulnerabilities associated with stablecoins have been explored in previous FSB and other reports.[47] Box 2 discusses potential financial stability implications from the use of tokenised deposits as settlement assets on DLT platforms. The BIS-CPMI report on tokenisation provides further considerations on the use of settlement assets on DLT platforms in the context of money and other assets.[48]

Box 2: Potential financial stability implications related to tokenised deposits

One potential candidate for settlement asset on DLT-based platforms is tokenised deposits. Tokenised deposits could follow the same practices and designs as for conventional commercial bank deposits and be developed as non-bearer instruments. However, if a tokenised deposit is designed as a transferable claim (i.e. akin to a bearer instrument), the token issuer's balance sheet[49] will not be updated when the token is transferred and, in some jurisdictions, simply possessing the token may be

46 BIS-CPMI (2024) discusses potential implications of tokenisation for settlement risk, e.g. by comparing atomic settlement in token arrangements with DvP and PvP settlement in traditional arrangements.

47 See, for example, Garratt and Shin (2023), Stablecoins versus tokenised deposits: implications for the singleness of money, BIS Bulletin No. 73, April; FSB (2023b), *High-level Recommendations for the Regulation, Supervision and Oversight of Global Stablecoin Arrangements: Final report*, July; and Bank of England (2024), *The Bank of England's approach to innovation in money and payments – Discussion paper*, July.

48 BIS-CPMI (2024).

49 It is important to note that the issuer's balance sheet and the DLT that records all the transactions are two different concepts. The DLT must always updated when the token is transferred.

enough to constitute a claim on the issuer.[50] As a result, these tokens might be able to circulate without the issuer's knowledge or control. Designing tokenised deposits in this way could introduce unique financial stability implications if not addressed by regulation and supervision, including the potential for a secondary market and a deviation from par that could affect the "singleness of money"[51] and which could undermine confidence in financial markets.

In addition, the programmability feature of DLT-based tokens could lead to automatic transactions based on specific pre-determined triggers. In the case of tokenised deposits, such automatic transactions could increase herding behaviour or the risk of (programmed) bank runs. Further, the stability of these deposits could decrease in the case where there is lack of clarity about the legal and regulatory status of tokenised deposits. This would include questions about whether tokenised deposits are covered by deposit insurance or whether they are treated equally with conventional deposits in bank resolution or insolvency, especially in the cross-border context.

3.2. Leverage

Rehypothecation[52] of tokenised assets could lead to the build-up of leverage in the financial system. The composability feature of certain DLT platforms could allow market participants to set up transactions involving the rehypothecation of tokens received as collateral. As in other contexts, absent the imposition of any regulatory limits, rehypothecation can facilitate the build-up of leverage. For example, investors could borrow tokens using a lending protocol and use their claim on these tokens to increase leverage.[53] The existence of multiple tokens and smart contracts on a common platform, if made interoperable, could also enable a wide range of tokens to be pledged as collateral for borrowing. Some of these may not be appropriate for prudent borrowing without substantial haircuts and, given the nascent state of tokenisation, there may not be adequate regulation in place stipulating minimum haircuts. The availability of market valuation for the token related to the underlying reference asset could ascribe legitimacy to and drive the prevalence of rehypothecation, compared with a non-tokenisation context.

3.3. Asset price and quality

The composability inherent to DLT technology, namely the ability to assemble different smart contracts and protocols to create new products, could introduce greater complexity and opacity to tokenised financial markets. The lack of transparency or understanding of the risks in complex smart contracts could undermine the ability of investors to properly assess the quality and price of tokenised assets. Not all tokenisation initiatives would necessarily be associated with complex

50 Conceptual arguments on different forms of tokenised deposits are based on Garratt and Shin (2023).

51 The 'singleness' of money refers to the principle that all forms of money should have the same value, be generally accepted as a means of payment and be interchangeable without loss of value with all other forms of money used in the economy. For further discussion of the implications of tokenisation for the singleness of money, see BIS-CPMI (2024). In some jurisdictions, the application of existing regulation may also mitigate risks to the singleness of money if applied in the context of tokenisation.

52 Rehypothecation is defined by the BIS as a particular form of re-use of client assets by a financial intermediary. In a re-hypothecation transaction, securities that serve as collateral for a secured borrowing (e.g. a margin loan extended to a hedge fund) are further utilised by the intermediary making the loan. When the reused collateral is in the form of securities that have been obtained as collateral by a party to a collateral agreement taking the legal form of a pledge, this practice is generally referred as re-hypothecation.

53 OECD (2022), *Institutionalisation of crypto-assets and DeFi–TradFi interconnectedness*, May.

and opaque instruments, but composability facilitates the ability to create complex contracts.[54] Token issuers could become analogous to originators of securitised assets in the traditional context and could introduce hidden (i.e. not disclosed or properly priced) risks for investors, that, at scale, might become systemic. This is particularly likely if issuers are not subject to or not compliant with regulations such as those applying to securitisation, including credit risk retention or disclosure rules. Furthermore, if a fund is tokenised in risk tranches (i.e. in a process that would effectively be akin to securitisation), assessing the relevant risks would involve an additional layer of complexity. Fractionalisation, lack of transparency, and resulting challenges in asset valuation could also lead to excessive risk taking by investors that are not qualified to assess and hold exposure to risks stemming from some tokenised assets.

The involvement of service providers that provide information on events that take place outside the DLT (oracles) can hinder accurate assessments of asset prices and quality in tokenisation. Information that could trigger smart contract actions could include corporate activity or market events. The existing regulatory and supervisory frameworks that apply to data providers in traditional markets may not entirely cover oracles in the context of DLT platforms, or oracles could be operating in non-compliance with applicable frameworks. Oracles may be vulnerable to hacks and manipulations exploiting smart contracts and implementation errors, which could compromise the accuracy of data supplied to DLT platforms. In addition, the multi-party and multi-asset nature of DLT platforms may introduce new risks. In traditional systems, centralised operators are responsible for checking the trustworthiness of the information provider. In decentralised arrangements, there may not be a similar focus on how to assess the trustworthiness of the information used in smart contracts, e.g. due to poor governance of the DLT or the oracle protocols and lack of commensurate risk management arrangements by token issuers. Thus, obtaining an accurate picture of asset price and quality of tokens may be hindered by reliance on unregulated or non-compliant oracles for pricing and valuation.

There is a risk of divergence between the prices of a token and the reference asset, or between tokens representing the same underlying asset on different DLT platforms or issued by different token issuers. There may be a variety of obstacles to the fungibility of the tokens and reference assets that affect redemption. These may include a lack of legal recognition of a token for off-chain purposes, legal enforceability of a token to reference asset redemptions, concerns over the reliability of the token issuer, mismatch in trading mechanisms or the operating hours of the tokenised market and reference asset market, and possibly higher perceived liquidity and valuation of the token due to its smaller unit (created by fractionalisation) and its utility in smart contracts. Such lack of fungibility could create fragmentation of liquidity and divergence in pricing of tokens and reference assets. In particular, asset prices may reflect not only the price of the reference asset, but also other features such as the use of a specific DLT, a jurisdiction's legal risk or the credit risk of a token issuer. In turn, the price divergence might create confusion among market participants and exacerbate redemptions in times of stress, especially if

[54] Similar dynamics were observed during the global financial crisis in 2008 when the complexity and opacity of securitised products created wrong incentives for some participants in the securitisation chains (e.g. sponsors of securitisations or loan underwriters) who were rewarded for the volume of securitisations (even with high credit risk) without economic penalties for the lack of accurate risk assessment and for introducing unrecognised risks to investors. Misaligned economic incentives have been mitigated by new regulations introduced in multiple jurisdictions (e.g. asset-level disclosures and risk retention or "skin in the game" requirements), and modern securitisation markets are significantly more transparent and robust than before the global financial crisis. See FSB (2024).

mechanisms in the traditional financial system that halt or limit the transmission of shocks (e.g. circuit breakers) are not present due to tokenisation platform design choices.

3.4. Interconnectedness

Some tokenisation features can give rise to novel interconnections and dependencies in the financial system. For example, a large integrated tokenisation platform that provides token issuance (non-settlement and settlement asset tokens), secondary trading and custody-type services to a wide array of financial institutions could create new interdependencies between institutions that are not directly connected to each other. These platforms may create these interconnections if they are not subject to, or are not compliant with, the rules separating different activities of financial intermediaries. The failure of a large-scale tokenisation platform could have negative spillover effects across a range of financial institutions, especially if the platform represented a significant portion of the tokenised products issued or traded by those institutions.[55]

Reliance on a limited number of third-party service providers to perform critical functions in tokenised asset markets could introduce concentration risks for market participants. Such concentration can manifest in various aspects of tokenisation, including the validators of the underlying blockchains, data centres hosting validator nodes, issuers, and custodians. When a small number of entities or infrastructure components dominate these critical functions, the failure or malfunctions of these concentrated points can have far-reaching consequences.

Programmability and automatic executions are examples of tokenisation features that introduce novel interconnection within the financial system. They may increase the possibility that events in one platform may influence and trigger inter-platform runs, or intra-platform runs (from one asset to another one within one platform). Tokenisation could expand the availability of financial products and services across borders and on a 24/7 basis. Notwithstanding the potential benefits for users, this could exacerbate the risk of regulatory arbitrage in cases in which the applicable rules are not consistent across jurisdictions, which could ultimately lead to a race to the bottom and threaten financial stability. Higher global interconnectedness could also widen and accelerate shocks in times of stress, potentially necessitating greater coordination across jurisdictions.

Some tokenisation features could also amplify vulnerabilities around interconnections in the financial system. As discussed above, potentially increased composability enabled by DLT technology could introduce greater complexity and opacity to the financial system, which would make it harder for relevant parties to identify and assess the complex interconnections.

3.5. Operational fragilities

Operational fragilities can exist both as tokenisation project-specific challenges (i.e. related to issuers or affiliated parties) and vulnerabilities inherent to the underlying DLT infrastructure.

---

55 Potential financial stability vulnerabilities brought by vertically integrated multifunction crypto-asset intermediaries (MCIs) were discussed in FSB (2023c), *The Financial Stability Implications of Multifunction Crypto-asset Intermediaries*, November.

Project-specific challenges

- **Third-party dependence**. One significant operational fragility lies in the dependence on, and coordination between, various intermediaries in the tokenisation process, such as DLT platforms and custodians. DLT-based workflows can differ significantly from traditional ones, posing operational challenges for intermediaries involved. For instance, custodians may face difficulties in maintaining robust private key [56] management and ensuring data integrity between distributed ledgers and traditional systems.

- **Permissionless blockchains**. Where financial intermediaries rely on permissionless blockchains for issuance, trading, or settlement of tokenised assets, there may not exist a contractual third party responsible for the management of operational risks stemming from that infrastructure. Therefore, the burden may shift to the intermediary using the infrastructure for its services to ensure proper management of these risks. In case of a serious incident, financial intermediaries may need to switch to alternative blockchains or to an off-chain equivalent solution, which may not be possible and would likely be disruptive to the market.

- **Smart contracts**. Smart contracts are an integral part of tokenisation, but their security practices are still evolving, giving rise to vulnerabilities that can potentially be exploited by malicious actors. From a technical risk perspective, smart contracts depend greatly on the precision of their code, and coding errors may not be easily resolved once deployed. Additionally, while smart contracts could theoretically allow for increased automation and composability, unanticipated operational and economic risks can arise from providing greater user flexibility in constructing bespoke or layered financial operations using smart contracts.

Fragilities in underlying infrastructure

To date, tokenisation projects focus largely on utilising DLT-based infrastructure for transaction processing. Such technological setups introduce trade-offs that could give rise to vulnerabilities including:

- **Limited capacity to process large volumes**. Certain tokenisation technologies may face limitations in processing large volumes of transactions. This issue can arise due to consensus protocols, the question of who is allowed to propose modifications to a ledger, the number of sponsors involved, the technological specifications of the DLT, and the fee structure for access to the DLT. While such vulnerability applies to both permissioned and permissionless blockchains, the relative magnitude of vulnerabilities may be lower for permissioned blockchains, which generally achieve faster consensus.

- **Continuous operations**. DLT-based infrastructure can operate on a 24/7 basis. Expectations for always-on operations may increase the operational demands on the infrastructure supporting tokenisation. As such, bottlenecks, or other operational issues

[56] Private keys are codes that allow users to conduct transactions.

may increase economic consequences. The continuous nature of blockchain operations also creates challenges in processing updates and fixing "bugs" in the underlying blockchain. This necessitates thorough testing and careful planning to ensure a smooth update process. The governance process through which such updates are made could pose additional third-party risks.

- **Permissionless networks**. Some operational fragilities may be more pronounced in permissionless networks, including issues related to settlement risk, immutability, and forking. Settlement finality in permissionless blockchain transactions relies on consensus mechanisms with no single party accountable for ensuring the finality of transactions and the point at which settlement is considered final may not be clearly defined.[57] The immutability, or irreversibility, of blockchain transactions can present fragilities in certain scenarios, such as instances of human error or involvement in fraudulent activities, where the need to reverse a transaction arises. Forking, or splitting a blockchain into two separate blockchains, is sometimes done to allow for repairs or upgrades to one part of the blockchain or because participants disagree about the governance of the blockchain. In certain blockchains, upgrades can be heavily debated and take a long time to implement. This can lead to chain fragmentation or delays in implementing repairs or upgrades, raising concerns about the long-term stability of the underlying blockchain.

4. Conditions under which tokenisation could affect financial stability

Use of tokenisation in the financial sector does not currently pose a material risk to financial stability, mostly due to its small scale. Additional factors that limit financial stability concerns associated with tokenisation include (i) tokenisation projects' current focus on permissioned (rather than permissionless) platforms; (ii) such projects do not yet leverage the programmability feature of DLT in ways that lead to complex transactions; and (iii) there is limited interconnectedness among DLT platforms and between those platforms and traditional markets.

It is not clear how tokenisation will evolve and which design models, if any, may gain traction, but tokenisation could have implications for financial stability under certain conditions, including:

- If the tokenised part of the financial system scales up significantly. This could be driven by increased adoption if the industry develops solutions to overcome the challenges discussed in Section 2. These solutions may include technological improvements that increase interoperability among DLT platforms and between DLT platforms and the traditional financial infrastructure, as well as industry or public-private sector initiatives on executing multi-asset transactions that meet minimum risk-management standards. Regulatory reforms and clarifications in some jurisdictions may also eliminate regulatory uncertainty around some tokenisation projects, which could further support financial institutions' increased engagement with such projects. In other jurisdictions, where

[57] Final settlement is defined as the irrevocable and unconditional transfer of an asset or financial instrument, or the discharge of an obligation by the FMI or its participants in accordance with the terms of the underlying contract. Final settlement is a legally defined moment. See CPMI-IOSCO (2012).

existing rules are already adequate, tokenisation projects over time may find approaches to scale up in a manner compliant with the applicable legal framework. The pace of change and concerns about market concentration may be accentuated if dominant players, such as large financial institutions or Big Tech firms with access to a large customer base, drive the adoption of tokenisation projects. Tokenisation could also lead to changing market roles and functions, which may reduce the effectiveness of existing risk management practices.

- If complexity and opacity of tokenisation projects increase, leading to unpredictable outcomes in times of stress. By potentially facilitating greater complexity, tokenisation may increase unrecognised risk accumulation and transfer, potentially generating unforeseen consequences. For example, shocks could spread more widely and in unexpected ways across the financial system due to complex interconnections among financial institutions and markets because of the composability and programmability features of DLT platforms, products, and services. Tokenisation could also lead to changing market roles and functions, which may reduce the effectiveness of existing risk management practices.

- If vulnerabilities associated with tokenisation (see Section 3) are not adequately addressed through oversight, regulation, supervision, and enforcement. These include mitigating the credit and liquidity risks of the type of settlement asset used; the potential for liquidity and maturity mismatch between the tokens and the reference assets; rehypothecation of tokenised assets; reliance on (non-regulated) third parties for critical services; and operational fragilities related to issuers or affiliated parties of a tokenisation project or the underlying DLT infrastructure.

In order to assess the financial stability implications of tokenisation, authorities should continue to monitor developments. Table 2 provides some examples of potential areas for ongoing monitoring through the gathering of quantitative (where possible) and qualitative data, to understand how the tokenisation market evolves and if these conditions materialise.

Table 2: Examples of key areas for ongoing monitoring

Key areas	Examples of indicators and information for monitoring
Adoption of tokenisation	• Size of the tokenisation markets and their changes over time • Investment in DLT platforms and tokenised assets by financial institutions and other players • Liquidity and transactional volume in tokenisation markets • Type of assets being tokenised • Profile of holders of tokenised assets • Scale of cross-border activity
Degree of interoperability and fragmentation between platforms	• Number and size of bridges between platforms • Amount of transactions between different platforms • Development of public and private initiatives around technological solutions for interoperability • Size of transactions through cross-chain interoperability protocols

Key areas	Examples of indicators and information for monitoring
	• Types of governance structures and decision-making mechanisms
Availability and choice of settlement asset	• Characteristics of settlement assets used in DLT platforms (e.g. transfer models and type of settlement asset)
Concentration in the market	• Involvement of systemically important financial institutions or other entities (e.g. large trading platforms). At the entity level, whether there are significant changes to their funding/ liquidity profiles and leverage ratios • Emergence of dominant (third-party) service providers • Dependencies on a single or small number of key technological infrastructures (e.g. DLT platform)
Involvement of third-party service providers	• Number and size of third-party service providers such as oracles and their regulatory/supervisory treatment.
Extent of automation/speed due to programmability	• Extent of the use of programmability features in typical tokenisation transactions • Number and types of actors with access to programmability features in platforms
Complexity of transactions	• Degree of involvement of complex transactions using programmability and composability • Size of rehypothecation and other leveraged transactions • Availability of liquidity savings mechanisms[58]

5. Conclusion

While the scale of DLT-based tokenisation is currently small, a number of financial market participants are investing in tokenisation projects and public sector authorities are assessing whether tokenisation offers benefits for financial systems or increases risks to investors and financial markets. The purported benefits include increased efficiency, including in clearing and settlement; reduced costs; the potential for increased variety of financial products and services; and an expansion of opportunities for the real economy and investors, including by making it possible to fractionalise ownership of assets. However, there are a number of impediments to scaling DLT-based tokenisation, including the lack of interoperability of platforms and the unavailability of safe settlement assets on the same platform (or fully interoperable platforms) for tokenised assets.

Due to its small scale, tokenisation does not currently pose material financial stability risks. However, DLT-based tokenisation's features have the potential to create financial stability concerns, particularly if tokenisation scales. Its vulnerabilities include the potential for liquidity mismatch, excessive leverage, interconnections, asset quality issues, and operational fragilities. They may lead to material financial stability risks when certain conditions are met, which requires authorities' close monitoring. However, there is a lack of information available regarding the size

[58] Liquidity-saving mechanisms are queuing arrangements for payments that operate alongside traditional real-time gross settlement (RTGS) systems. See Martin and McAndrews (2008), *An Economic Analysis of Liquidity-Saving Mechanisms*, Federal Reserve Bank of New York Economic Policy Review, September.

and composition of the tokenised assets market, as well as potential uncertainty in the legal, regulatory, and supervisory frameworks that apply to tokenised assets in certain jurisdictions.

In light of the findings in this report and the rapid evolution of the technologies that facilitate DLT-based tokenisation, the following are initial issues for the FSB, SSBs and national authorities:

- Consider ways to address data and information gaps in monitoring tokenisation adoption. Authorities could use some of the key indicators and metrics in Table 2 for ongoing monitoring. Where data gaps are identified, authorities may wish to explore various sources of data and information including through reporting by regulated entities, information from market participants (e.g. data analytics companies) and open-source data available on DLT platforms and other public information sources. Addressing data and information gaps may become increasingly difficult if tokenisation scales mostly on permissioned DLT platforms.

- Consider ways to increase understanding of how tokenisation and its related features fit into legal and regulatory frameworks and supervisory approaches. These efforts should take into consideration ongoing relevant work by SSBs, including the BCBS, CPMI and IOSCO, as well as by international organisations such as the BIS. Given the rapid developments in this area, authorities may wish to share experiences and assess if existing regulatory and supervisory frameworks adequately address the vulnerabilities identified, including with respect to the regulatory perimeter. The FSB and relevant SSBs may also wish to consider ways to support this process.

- Continue to facilitate cross-border regulatory and supervisory information sharing on tokenisation. Given the potential global reach, continuous operations, and multi-asset nature of tokenisation markets, regulators and supervisors may benefit from enhanced cross-border and cross-sectoral information sharing. To this end, the FSB working with SSBs could consider ways to facilitate information sharing, including monitoring developments across member jurisdictions given the nature of tokenisation that allows multiple assets to be traded and settled on the same platform or interoperable systems.