BIS

Tokenisation in the context of money and other assets: concepts and implications for central banks

Report to the G20

Joint report by the Bank for International Settlements (BIS) and Committee on Payments and Market Infrastructures (CPMI)

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Executive summary

For centuries, economic and financial transactions have been facilitated by tokens acting as a medium of exchange and/or representing some type of value. This report focuses on the much more recent creation of digital tokens on programmable platforms that provide an infrastructure on which multiple issuers, investors, payers and payees may issue, trade and settle transactions with money and other assets.

For the purposes of this report, tokenisation is defined as the process of *generating and recording a digital representation of traditional assets on a programmable platform*. This definition, which builds upon the definition in BIS (2023a), reflects that the issuance, recording and transfer of tokens relies on the execution of applications that exist on programmable platforms.

- *Digital tokens* are entries in a database that are recorded digitally and that can contain information and functionality within the token themselves. Digital tokens can represent financial or real assets.
- *Programmable platforms* are the technologies that allow eligible participants to develop and execute applications that update a common ledger. In the context of money and other assets, one of the technologies that has gained prominence is Distributed Ledger Technology (DLT).

This report uses the term *token arrangement* to indicate the infrastructure that supports the use of digital tokens in financial transactions. A token arrangement may include more than one programmable platform to the extent that functions are performed on several platforms or there is some other interdependency across platforms. Further, an arrangement includes financial market functions whereas a platform could theoretically allow for applications or programs to perform other non-financial functions.

Token arrangements can be designed to enable multi-asset, multi-function and multi-party financial transactions and services. A token arrangement might record both money and other assets. This differentiates it from existing payment, clearing and settlement arrangements, which typically hold money on separate ledgers. The standardisation of certain digital token features may facilitate the coexistence of different asset types on a single programmable platform. Tokenised assets can then be traded and settled using applications built on the platform. These applications may allow for bundling different functions and creating new ones. For instance, an application could combine pre- and post-trade services – financial market functions that are typically separated in existing arrangements. Token arrangements may also employ automation and conditionality of transactions across a range of functions and/or asset types, potentially affecting the execution of financial market functions if allowed by legal and regulatory frameworks. Overall, this could expand the set of operationally feasible options for carrying out financial transactions.

Tokenisation can bring both opportunities and risks. Platform-based intermediation brings the potential to reduce the frictions present when disparate systems are needed to issue, trade and settle different types of assets. This can potentially decrease transaction costs, enable new use cases and better match supply and demand. Lower frictions may improve the allocation of resources and hence support capital allocation. The technology provides features such as conditionality, data reconciliation and automation, which may also decrease costs and support the development of innovative use cases.

As with existing recording, payment, clearing, and settlement systems, the potential capacity of token arrangements to improve financial system safety and efficiency will require sound governance and risk management. The well-known risks of existing systems apply, such as those related to credit and liquidity risks, custody, access policies, operational and cyber risks. These risks may materialise in different ways due to the effects of token arrangements on market structure, eg due to a change in the roles played by intermediaries when previously separate functions are combined on one platform. Risks may also emerge owing to conflicts of interest due to the combination of functions within a single entity, or a concentration of activity in one or a few arrangements.

On balance, the future development of token arrangements remains uncertain, and many outcomes are conceivable. Looking forward, tokenisation may have implications for the roles of central banks in payments, monetary policy and financial stability. A primary consideration for central banks is whether, and to what extent, to react to ongoing private sector tokenisation initiatives. For example, central banks could consider ways to foster interoperability if markets develop in a fragmented manner. A second consideration is whether and how central banks assess the trade-offs and the appropriate balance between different types of settlement assets in token arrangements. This may include how or in what form central banks could provide central bank money as a settlement asset for token arrangements. A third consideration concerns identifying token arrangements that may already, or potentially in the future, meet the criteria to be subject to regulation, supervision and oversight at the individual jurisdiction level. They might also be subject to international standards such as the PFMI. Relevant authorities might consider how to cooperate, both within and across jurisdictions. A final consideration relates to the potential impact of token arrangements on monetary policy implementation, for example through changes in the structure of regulated markets or the demand for central bank versus other types of money.

1 Introduction

A much discussed topic in financial markets is tokenisation, which for the purposes of this report is defined as *the process of generating and recording a digital representation of traditional assets on a programmable platform*. The CPMI has published on a range of topics related to features commonly associated with tokenisation, including various settlement models and settlement assets, digital currencies and distributed ledger technology (DLT).[1] Recent work by the BIS envisions a future financial system in which tokenisation plays an important role (BIS (2023a)).

Though the concept and use of tokenisation first developed in cryptoasset markets, a number of projects and experiments in regulated financial markets have increased the relevance of tokenisation for central banks in recent years. Initiatives in the regulated perimeter to date have focused on the potential for tokenisation to address existing frictions in financial markets and are exploring new use cases and functions, potentially making activities more efficient. Projects vary along a number of dimensions including what specific process or action is referred to as "tokenisation". However, many projects are similar in their reliance on DLT as the underlying technology supporting tokenisation.

In the light of these developments, the G20 has requested that the BIS and CPMI examine the meaning of tokenisation in the context of money and other assets, and how to envision a tokenised environment that builds on the best attributes of the current monetary and financial system, while discussing potential future implications. The purpose of this report is to describe ways that tokenisation may affect the functioning of regulated financial markets. It critically analyses opportunities, challenges and risks, and identifies the most relevant implications for central banks and, more broadly, for the global financial system.

Tokenisation's effect on the future financial system remains uncertain, with a spectrum of potential adoption. At one end of the spectrum, it would be widely adopted for a variety of use cases and certain arrangements offering such use cases could become systemically important financial market infrastructures (FMIs). At the other end of the spectrum, tokenisation would be applied to specific use cases with limited effects on financial markets broadly. Some future states are unlikely to be seen in regulated financial markets and are therefore excluded from this report. For example, although tokenised systems could allow for an unlimited set of anonymous market participants to engage in multiple functions and to have access to multiple assets, this outcome is highly unlikely in regulated financial markets. Several factors will constrain the extent to which different assets and markets are tokenised and entities play various roles. These include investment trade-offs as well as policy, legal and regulatory constraints.

The remainder of this report is organised as follows. Section 2 examines the concept of tokenisation. Sections 3 and 4 provide a high-level overview of opportunities, risks and challenges. Section 5 discusses potential implications for central banks related to market developments, the choice of settlement assets, oversight and monetary policy. Section 6 concludes.

2 Tokenisation of money and other assets

The term "tokenisation" has no generally accepted definition, even among those in the financial industry. It has been used inconsistently in connection with various initiatives, making any attempt at conceptual analysis preliminary. Tokenisation in this report refers to *the process of generating and recording a digital*

[1] See Committee on Payment and Settlement Systems, *Delivery versus payment in securities settlement systems*, September 1992; CPSS, *Settlement risk in foreign exchange transactions*, March 1996; CPSS, *The role of central bank money in payment systems*, August 2003; CPMI, *Digital currencies*, November 2015; CPMI, *Distributed ledger technology in payment, clearing and settlement – an analytical framework*, February 2017; and CPMI, *Wholesale digital tokens*, December 2019.

representation of traditional assets on a programmable platform. The term "recording" is used to capture the creation of entries in a database. The term "programmable" is used to underline that these entries can contain both information and applications or programs that can be executed on the platform based on pre-defined logic. The term "assets" is used to indicate that these entries should represent real or financial assets to qualify as a token for the purposes of this report. A standard definition of assets is used, one that includes money as a subset.[2]

For the purposes of this report, tokenisation is defined as the process of *generating and recording a* digital *representation of traditional assets on a* programmable *platform*. This definition, which builds upon the definition in BIS (2023a), reflects that the issuance, recording and transfer of tokens relies on the execution of applications that exist on programmable platforms.

- *Digital tokens* are entries in a database that are recorded digitally and that can contain information and functionality within the token themselves. Digital tokens can represent financial or real assets.
- *Programmable platforms* are the technologies that allow eligible participants to develop and execute applications that update a common ledger. In the context of money and other assets, one of the technologies that has gained prominence is Distributed Ledger Technology (DLT).

This report uses the term *token arrangement* to indicate the infrastructure that supports the use of digital tokens in financial transactions. A token arrangement is defined as the programmable platforms and/or participating entities that enable financial market functions by utilising digital tokens. Thus, an arrangement may include more than one programmable platform to the extent that functions are performed on several platforms or there is some other interdependency across platforms. Further, an arrangement includes financial market functions, whereas a platform could theoretically allow for applications or programs to perform other non-financial functions.

Digital tokens cannot exist independently of the programmable platform, since the issuance, recording and transfer of tokens relies on the execution of functions on the platform. Nevertheless, a separate discussion of digital tokens and programmable platforms is justified, since tokenisation creates a distinct separation in the management of digital assets and their hosting platform (Budau and Tourpe, 2024).

2.1 Tokens

In an abstract sense, a token is a representation of something of value. In the context of money and other assets, tokens may represent claims on or representations of real or financial assets. Tokens can be useful to the extent that they facilitate the processes of issuing, storing and/or transferring value.

The use of tokens is not new. Historical research shows that tokens pre-date the invention of writing and are as old as accounting itself (see Schmandt-Besserat (2015)).[3] With the advent of the electronic age, physical tokens evolved into tokens in electronic form. Electronic bookkeeping accelerated paper-based processes, allowing accounts to be updated with phenomenal speed (BIS (2023a)).

[2] Assets have been defined as a store of value, over which ownership rights are enforced and from which their owners may derive economic benefits by holding or using them over a certain period of time; see IMF (2016), Monetary and financial statistics manual and compilation guide. Asset can be distinguished further, such as tangible and non-tangible assets, and financial and non-financial assets. Financial assets are a subset of all assets and consist of all financial claims, including for example deposits, debt securities, loans, equity and derivatives.

[3] As early as 7500 BC, tokens in the forms of cones, spheres and discs were used to represent various kinds of merchandise prevalent in the farming economy of the time. Seashells were used as money as early as 1200 BC in China and continue to be used in some parts of the world.

Throughout the ages, different mechanisms have been used to enhance trust in the value of the token, such as underlying assets in custody; norms (eg when used in small social groups); institutions; laws; and specific characteristics of the token that make them easily identifiable, rare or may prevent counterfeiting (including eg physical safety features for physical tokens, or cryptography for digital tokens).

The remainder of this report considers digital tokens that are issued by regulated financial entities that represent financial or real assets. Compared with pre-existing tokens, digital tokens are entries in a database that are recorded digitally and that can contain information and applications within the token themselves. This allows tokens to store something, such as details related to the value of the asset it represents and its owners. Further, it allows tokens to do something, such as to follow the rules and logic governing a token's use on the platform (see Aldasoro et al (2023), Schär (2024)). By this, digital tokens are programmable in the technological sense, as described in Box 1.

2.2 Platforms

In the context of this report, a platform refers to the technologies that allow participants to develop and execute applications that update a common ledger. Platforms exhibit two features: first, they contain a ledger with records that can be updated using some database protocol. Second, platforms host applications developed and used by the participating entities. Applications are computer programs stored and executed on the ledger that follow "if this then that" logic. To do so, programmable platforms contain an execution environment that allows the applications (known as smart contracts) to run. In the context of money and other assets, one of the technologies that has gained prominence is DLT.[4]

Applications allow for actions conditional on information in or outside the ledger to be executed on the platform. For instance, a transfer of a digital token could be executed if and only if a corresponding transfer of digital tokens occurs. By this, applications could replicate existing financial market functions, such as delivery versus payment (DvP) and payment versus payment (PvP) settlement. The common and flexible infrastructure of platforms allows them to host multiple potentially interoperable applications. This could allow multiple financial market functions to be integrated into a single platform, for such functions to be bundled and possibly also for new ones to be created.

Applications could be deployed and executed potentially by all eligible participants and not only by the infrastructure provider itself. Through standardisation of programming, deployment and execution, applications become interoperable. Depending on the degree of openness, participants can inspect an application's internal logic. Overall, such a platform would allow participants to build, combine and use platform functionality.

Box 1. Programmability

Programmability is a method to automate operations by executing transactions when certain predefined conditions are realised. This concept already exists in conventional arrangements, but flexible programmability has been cited as one of the core features and benefits of tokenisation.

Transactions can be programmed between users of the same infrastructure (this could be a bank or a single platform) or between users of two different infrastructures (eg two different banks or two different platforms). The first model – internal programmability ('internal') - has been the most common case observed in tokenisation initiatives to date. It relies on protocols or codes contained in the token arrangement that execute when certain conditions are met (smart contracts). The second model – external programmability ('external') - generally uses external application programming interfaces (APIs), often relying on message exchange, to program transactions between systems. Such cross-infrastructure connectivity is often also supported by smart contracts.

[4] DLT is defined in this report as the processes and related technologies that enable participants to securely propose, validate and record updates to a ledger that is potentially shared across participants (CPMI (2017)).

In the external programmability model, the platform can be programmed. Programming the platform allows setting the rules that govern the common infrastructure. It is typically performed by the platform operator. Differently, in the internal model, programming the token sets the specific information, definitions, rules and logic that define a token and govern its behaviour within a platform. There are typically three entities that could be responsible for programming the token within the token arrangement, depending on its eligibility policy: the token issuer who determines the initial parameters of the tokens, the token developer who programs on the platform, and the end user who holds, transfers or uses the token.

Finally, due to the conditional automation of smart contracts in internal programmability, tokens can interact in predefined ways. Further, programmability could facilitate the combination of different applications or tokens (so-called composability).[5]

2.3 Token arrangements

Tokenisation may facilitate market standardisation and programmability of assets. This could expand the use of the platform-intermediated provision of financial services throughout the securities life cycle (GFMA (2023)). This report uses the term "token arrangement" to describe the programmable platforms and/or participating entities that enable financial market functions by utilising digital tokens.

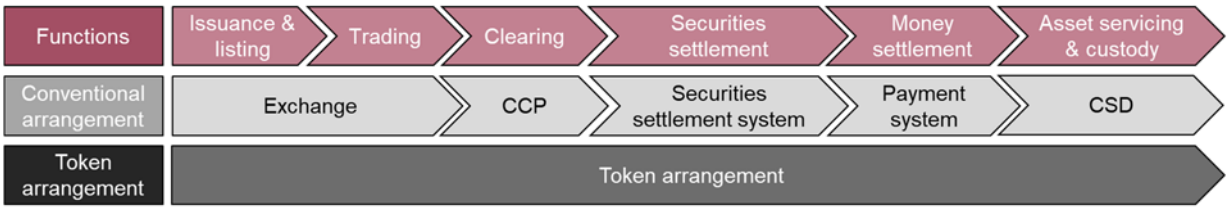
Currently, functions necessitated through the life cycle of a financial transaction are often performed by separate entities across multiple activity- or asset-specific arrangements (hereafter, conventional arrangements). Some of these functions may be performed by an entity using its own arrangement while others are performed using shared or multilateral arrangements. The functions and entities that facilitate them are shaped by legal frameworks, regulation, operational feasibility, market conventions and considerations of suitable risk management and governance. The degree of separation or combination varies across jurisdictions.

The platform-intermediated provision of financial services may allow for a different market structure compared with conventional arrangements. Token arrangements could be multi-asset, multi-function and multi-party. They might host different types of assets in token form, including money and other assets, in contrast with many existing arrangements in which money is typically held on separate ledgers (Bindseil and Pantelopoulos (2023)). Applications built on top of a common infrastructure allow for the integration of different functions in a token arrangement, which could cover the whole or a part of the life cycle of a financial transaction, ie from issuance to trade and post-trade processing. While many current token arrangements focus on one or a few functions, they may – in principle – cover all traditional financial market functions (Figure 1).

The internal programmability might change how financial market functions are performed. The ability to condition transfers based on pre-defined, contingent logic might reduce the dependency on intermediaries to the extent that functions that previously relied on manual processes may be automated (see Box 2). For instance, this ability could allow digital tokens to be directly held and transferred by participants without involvement of a third party. Internal programmability may also facilitate situations where claims on different assets may be governed by different sets of rules. Overall, internal programmability could – if consistent with governing laws, applicable contracts and other relevant decision-making processes – expand the set of operationally feasible options for carrying out financial transactions (see BIS (2023a)).

[5] See Lavayssière and Zhang (2024) for the terminology on internal and external programming. Toh et al (2024) introduce a similar distinction between "bank-side programmability" (which broadly corresponds to "internal programmability" used in this report) and "client-side programmability" ("external programmability").

Figure 1. Financial market functions and conceivable arrangements[6]



CCP = central counterparty; CSD = central securities depository.
Source: Adapted from BIS, SIX and SNB (2020) and GFMA (2023).

Token arrangements could host multiple parties and, depending on the access criteria and if legally permitted, parties that currently rely on intermediaries could participate more directly compared with conventional arrangements. For instance, regulated issuers and investors could both have direct access to the arrangement instead of relying on intermediaries. Also, parties from different jurisdictions could potentially interact on a common platform. Compared with conventional arrangements, this could lead to a change in the roles of intermediaries and potentially affect market structure, but at the same time it raises new and intricate governance questions, among others.

At present, DLT is the most common technology underpinning token arrangements.[7] DLT provides a method of updating the arrangement's ledger and for applications performing various functions to communicate with the ledger and one another. The tamper-resistance of records of ownership and the ability to share data supports consensus and fosters trust for digital tokens' use in token arrangements (see Zellweger-Gutknecht (2019)).

3 Opportunities and adoption of token arrangements

Tokenisation is making inroads into the regulated financial sector. Regulated private institutions and the public sector are investing in initiatives that cover a number of use cases, such as tokenised bond issuance, tokenised commercial bank deposits and tokenised repurchase agreements, among others.

Token arrangements entail potentially substantial investment costs. Alternatively, opportunities may also be achieved with conventional financial market arrangements Moreover, the extent to which the opportunities are achieved depends on the users' demand for tokenisation-enabled solutions and jurisdictions' legal and regulatory regimes. In view of this uncertainty, investment by the private sector will be based on its assessment of the expected private returns versus the private costs. Likewise, for public institutions, investment in tokenisation will be based on expected social returns and social costs.[8] This may include aspects such as enhancing cross-border payments, improving financial inclusion or other public policy priorities in individual jurisdictions.[9]

6 This figure is a generalisation. In many jurisdictions today, multiple functions are combined. Additionally, token arrangements make a wide range of possibilities feasible. They would not have to combine all functions if other designs were preferable.

7 Although analysis in this report references DLT as underpinning current examples of tokenisation, what technology may be used in the future is uncertain, and this report does not endorse any particular technology.

8 For example, public institutions could factor in externalities and network effects related to the creation of an open contestable market on a public platform, or the creation of trust due to settlement in central bank money. At the same time, authorities may also factor in social costs such as governance or sovereignty costs.

9 For instance, the Eurosystem is reflecting on the potential of a European unified ledger to advance the capital markets union. The Brazilian central bank is developing the digital Brazilian real, Drex, on a DLT platform, aiming to enable innovative use cases and favour financial inclusion.

3.1 Opportunities

The ultimate economic functions of financial markets are to decrease information and transaction costs, promote risk-sharing, and as a result improve resource allocation and economic welfare. In practice, financial markets and the infrastructures that support them exhibit frictions, potentially resulting in a socially sub-optimal allocation of resources, realised output and welfare. For example, payments, especially across borders, are challenging, resulting in high costs, slow speeds, low transparency and limited access, as laid out in the G20 roadmap (FSB (2020)). Specific challenges in domestic markets vary by jurisdiction.

Tokenisation initiatives launched by the private and public sectors largely aim to address current frictions by attempting to streamline the various aspects of financial market transactions or, in some cases, the entire end-to-end transaction. This, in turn, may provide opportunities to improve the safety and efficiency of financial markets through greater transparency, reduced transaction or information costs, higher speed and improved risk management. Opportunities may also arise from enabling new use cases and functions, including fostering financial inclusion.[10]

It is important to note that not all frictions present in existing payment, clearing and settlement arrangements can or should be fully addressed by adopting token arrangements. Certain frictions present in these markets are in place to achieve particular policy and risk management objectives and would be present to some degree regardless of the arrangement used (eg anti-money laundering / combating the financing of terrorism (AML/CFT) compliance and central bank access policy).

Automation and the combination of functions

Token arrangements may facilitate the availability of different assets and the ability to combine multiple functions on a single programmable platform, which in turn may achieve greater flexibility of product offerings and streamlined processing of complex transactions. For example, token arrangements may integrate tokens issued by different entities (representing currencies or assets) onto a single platform. This may allow for the combination in one infrastructure of functions that currently take place across multiple separate arrangements due to assets being recorded in disparate systems, potentially reducing costs enough for transactions between assets that previously were not economically feasible to occur.[11]

Token arrangements may also present new opportunities to employ automation and conditionality of transactions across a range of functions and/or asset types. Transaction automation and conditionality are used in existing payment and settlement systems but may provide less flexibility in the sense that they are typically limited by the assets and/or functions conducted in the arrangement, or require complex connections across arrangements (eg through external APIs). As such, existing systems may not allow users to condition their transactions on every relevant factor. Token arrangements that contain multiple assets and/or functions may offer more flexibility for conditional transactions within the arrangement by allowing for transactions to be combined and their execution to be automated, potentially depending on a complex set of criteria (so-called "composability"). An example is the simultaneous and conditional settlement of two linked FX transactions that convert one currency into the US dollar and subsequently the US dollar into a third currency. Another example is the automation of pricing, transaction execution and settlement through programs (smart contracts) that can hold and conditionally transfer tokens (liquidity pools).[12] Both examples might facilitate cross-border trading and settlement.

The flexible automation allowed for by token arrangements may also improve asset servicing such as automating corporate actions, including dividend and interest payments, or shareholder voting.

[10] See Carstens and Nilekani (2024).

[11] For example, the BIS has identified tokenisation as a potential means of addressing the frictions in the current monetary system, especially by consolidating functions including messaging, reconciliation and settlement in trade and post-trade processes (BIS (2023a)).

[12] See eg Project Mariana (BIS (2023b)).

These payments could also be made conditional on investor type, including by being tailored to specific groups of investors or asset holders, though only if compliant with local regulations.

Straight through processing and transparency

A number of tokenisation initiatives aim to improve post-trade operations by providing greater transparency in record-keeping.[13] In some existing payment and settlement systems, in particular with the use of correspondent banks, users may rely on infrequent confirmation messages to reconcile their transfers between and within systems. By synchronising the state of the ledger and transmitting it to (a subset of) participants in a single technical environment, platforms eliminate or reduce the need for coordination between systems and the need for parties to update and reconcile separate ledgers. In addition, the use of a common platform for information-sharing may reduce the need for manual intervention and eliminate unnecessary duplication of processes across financial institutions (eg in meeting AML/KYC compliance requirements).[14,15]

Risk reduction and cost-efficiency

Other tokenisation initiatives consider how to streamline asset issuance.[16] Traditionally, the issuance process for a range of assets is costly and time-consuming due to the involvement of many parties and manual processes, among other reasons. Potentially improved flexibility for issuers in terms of asset functionality and standardisation of processes may expedite the time to market, require fewer intermediaries or provide competitive discipline to existing intermediaries. Overall, such standardisation and automation may lower costs and reduce barriers to entry in capital markets. This could enable new issuances or facilitate shared or fractional ownership of existing assets, including those assets that are less liquid in the current market environment, reaching new sources of investor demand. Legally permitting, tokenisation could also enable participants to directly issue or agree on the conditions of a contract regarding a specific token.

With respect to clearing and settlement, tokenisation initiatives aim to deliver atomic settlement of transactions involving multiple legs (eg Delivery versus Payment (DvP) or Payment versus Payment (PvP)) if relevant conditions are satisfied (see Box 2). With atomic settlement all legs of a transaction are executed or none of them are executed. In the case of DvP and PvP, atomic settlement addresses principal risk by conditioning the final settlement of one obligation upon the final settlement of the linked obligation.

While DvP and PvP settlement arrangements exist today, token arrangements may facilitate or expand the use of DvP and PvP if multiple assets (and/or currencies) become available for settlement on the same platform. Token arrangements could potentially expand DvP or PvP to facilitate settlement of all legs of multiple linked transactions between multiple parties simultaneously (see Lee et al (2022)).

Some tokenisation initiatives aim to eliminate the time gap between trading and settlement, which is usually delayed by one or multiple days. Atomic settlement would happen immediately once a trade has been agreed upon (see Lee et al (2022)). As a result, settlement fails would be eliminated, since traders would only be able to engage if both legs of the trade can settle immediately. Moreover, intermediaries could be reduced as clearing would become obsolete.[17] On the flip side, liquidity needs

[13] Eg RLN, HSBC-Orion, JPMorgan Onyx.

[14] Different jurisdictions may have different requirements and these should not be perceived as duplicative efforts.

[15] This potential shared compliance solution is one of the areas of investigation included in an ongoing public-private project, Project Agorá (BIS (2024)).

[16] Eg Goldman-Sachs DAP, BNP AssetFoundary.

[17] For instance, central counterparties would no longer be needed.

for instant settlement are higher than in arrangements using netting, and liquidity management would become more complex.[18]

Overall, changes to the clearing and settlement process could result in decreased settlement risk and reductions in intermediation, which in turn could reduce costs. However, the net effects of such changes to the settlement process should be considered carefully.

Box 2. Combining assets and functions: delivery vs payment (DvP) case study

In the current financial system, DvP can be achieved through different approaches. In some cases, settlement of a securities transaction can involve settlement in two separate systems operated by separate entities: a securities settlement system to settle the transfer of securities and a payment system to settle the funds transfer. To address settlement risk, DvP ensures that final settlement of one leg of the transaction occurs if and only if final settlement of the other leg occurs, however simultaneous settlement of obligations is not necessarily required. With separate systems, this settlement process can be more complex. For example, securities may be blocked in the securities settlement system awaiting payment before being released to the buyer. In other current systems, delivery and payment occur in the same system, some of which operate with a pure real time gross settlement (RTGS) model and others which employ liquidity savings mechanisms on top of the RTGS.

A programmable platform may support different types of money and other assets, enabling atomic delivery and payment within the same platform. However, even in these platforms, securities (or funds) are generally blocked until payment (or delivery) is completed.

In a programmable platform, the buyer and supplier could write and deploy to a single platform one or more programs attaching specific conditions to the buyer's token, including reserving the tokens required for payment from the buyer and determining the set of conditions under which payment is made to the seller, potentially increasing flexibility to meet end user needs.

3.2 Adoption of token arrangements

Investment in innovations such as tokenisation are based on a risk versus return perspective. This perspective might be different for the private and public sectors. Investments for both will probably depend on the degree of adoption of tokenisation. The investment trade-off framework introduced below may help to explain the types of tokenisation initiatives to date and the pace of investment, and provide some insights on the outlook for tokenisation.

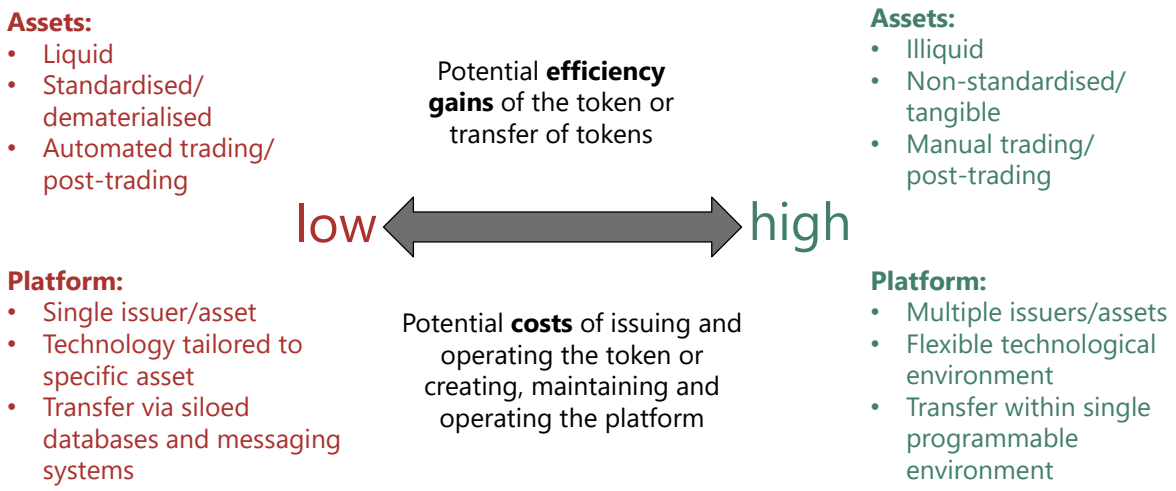
Investment trade-offs

The returns to tokenisation of a particular asset may be higher for assets which are more illiquid (with lower current trading volumes), less standardised (eg over-the-counter derivatives) and/or in non-electronic intangible form (Figure 2) than for those which are more liquid and standardised and are processed by market infrastructures (central securities depositories (CSDs), central counterparties (CCPs), securities settlement systems (SSS)) that ensure control of the various risks that may arise (credit risk, settlement risk, liquidity risk). At the same time, the cost of tokenisation for such less standardised assets may also be higher, thus explaining why such assets are not in electronic or intangible form already. In addition to direct investment costs, some implicit costs may exist, eg those related to a potential lack of legal certainty and regulatory clarity (see Section 4). As a result, early token arrangements have involved

[18] Current implementations in token arrangements tend to settle both legs of the transaction on a gross basis (eg DvP model 1; see CPSS (1992)) and they eliminate the time gap between trading and settlement, resulting in substantial liquidity costs due to pre-funding. At the same time, there is a trade-off with the potential increased velocity of money and assets due to simplified reconciliation and shorter settlement times, making money and assets immediately available to their holders and lowering opportunity costs from tied-up liquidity.

relatively small initiatives covering narrow scopes. Over time, as the market matures and network effects are realised (see Section 3.3) and the legal and regulatory framework evolves, the range of assets to be tokenised may expand, and the returns to doing so may also be higher (Aldasoro et al (2023), GFMA (2023)).

Figure 2. Investment trade-offs: greatest efficiency gains may come with highest costs



The returns to building new token arrangements may be large if there is currently no centralised infrastructure for recording issuance, trading and settling assets. In contrast, payment, clearing or settlement arrangements that already offer efficient solutions to their clients may see little or no benefit from tokenisation. Investment decisions by providers of platforms may also depend on the degree to which users of or intermediaries on the platform are investing in building applications on top of the core infrastructure. Investment decisions also may take into account the costs related to a number of risk factors when investing in tokenisation, including legal, regulatory and governance risks (see Section 4), among others.

Current state of tokenisation

Although the scale of token arrangements is currently small, initiatives that have reached the production stage are increasing in scale and scope.[19] These initiatives vary in terms of whether they are run by single firms or are joint projects. This could be a reflection of the investment trade-offs faced by the private sector and the necessity of network effects to support viable token arrangements (see below). Private sector projects also vary in terms of the assets present in the arrangement, including the type of settlement asset used (eg stablecoins, commercial bank money). As regards the public sector, the emphasis has primarily been on central bank money as a settlement asset in token arrangements and a number of central banks are actively exploring how programmable platforms could be implemented.[20] The BIS Innovation Hub has been leading a variety of projects; see Box 3.

[19] For example, tokenised repo transactions with a volume of more than one trillion US dollars are facilitated monthly (see McKinsey (2023)). Payments with a volume of over one billion US dollars per day are settled (Ghosh (2023)). Moreover, the volume of tokenised bond issuances is on the rise (ICMA (2024)). Turning to investments in infrastructures, large banks have continued to invest in platforms. However, according to Forbes (2024), only the largest banks continue to pursue proprietary projects, while the others tend to have shifted to consortiums and joint projects.

[20] MAS (2024), SNB (2024) and the BIS Innovation Hub projects including project Agorá.

Box 3. BIS Innovation Hub projects involving tokenisation

The BIS Innovation Hub (BISIH) is experimenting with tokenisation as it explores the future of central banking and the frontiers of the financial system (Table 1). The work so far has primarily focused on the settlement of tokenised assets in central bank money and on improving cross-border payments. Most projects have involved multiple central banks and have often been done in collaboration with the private sector.

An overview of BIS Innovation Hub projects involving tokenisation — Table 1

	Helvetia[1]	Jura[2]	Dunbar[3]	Mariana[4]	Agorá[5]	Promissa[6]	Genesis[7]	Dynamo[8]
BISIH Centre	CH	CH	SG	CH and SG	Hub-wide	CH	HK	HK
Currencies	CHF	CHF, EUR	AUD, MYR, SGD, SAR	EUR, SGD, CHF	EUR, JPY, KRW, MXP, CHF, GBP, USD	CHF, USD, SDR	HKD	HKD
DLT used	Corda	Corda	Corda, Quorum	Ethereum	TBD	Canton	Stella, Hyperledger, Canton, RDOS	Ethereum
wCBDC	✓	✓	✓	✓	✓	×	×	×
Tokenised deposits	×	×	×	×	✓	×	×	×
Tokenised digital assets	✓	✓	×	×	×	✓	✓	✓
AMM[9]	×	×	×	✓	×	×	×	×
PvP	×	✓	✓	✓	✓	×	×	×
DvP	✓	✓	×	×	×	✓	✓	×

✓ = tested; × =not possible/out of scope; PvP = payment versus payment; DvP= delivery versus payment; AMM = automated market-makers; RDOS = regulated DeFi operating system.

[1] Tokenised assets settlement in wCBDC [2] Cross-border settlement with wCBDC. [3] International settlements using multi-CBDCs. [4] Cross-border exchange of wCBDCs using AMMs. [5] Tokenisation of central bank money and commercial bank deposits. [6] Tokenisation of financial instruments. [7] Tokenised retail green bonds (Genesis 1.0); smart contract-based carbon credits (Genesis 2.0). [8] Smart contract programmability in trade finance. [9] AMMs are smart contracts that allow traders to exchange one cryptoasset – or tokenised assets more generally – for another, by drawing on a common pool of liquidity.

Source: BIS Innovation Hub.

The Helvetia project series and Project Jura used tokenised wholesale central bank money to settle tokenised assets domestically and cross-border, respectively. The experiments showed that tokenisation can reduce the complexity of securities settlements by facilitating simpler and automated processes. They also confirmed that a wholesale CBDC (wCBDC) (understood as wholesale tokenised central bank money) can play a critical role as a safe and neutral settlement asset for international financial transactions. The Swiss National Bank has taken forward the Helvetia investigation to a pilot stage, offering wCBDC for the settlement of commercial transactions with digital bonds.

In cross-border payments, several projects have focused on tokenisation and settlement (Dunbar) and trading (Mariana) of wCBDCs. They shared similar final goals to make cross-border payments better but aimed to achieve them through different methodologies, architectures and technologies (BISIH (2023)). Beyond meeting core requirements, the experiments (Jura, Dunbar) highlighted potential operational efficiencies compared with current arrangements. Notably, bringing multiple currencies onto a common multi-CBDC platform with participants transacting directly reduced overheads, made settlement faster and increased operational transparency (BISIH (2022)). Project Mariana tested the cross-border trading and settlement of hypothetical Swiss franc, euro and Singapore dollar wCBDCs. It pioneered the use of automated market-makers for the cross-border exchange of wCBDCs, demonstrating technical feasibility while fulfilling central bank requirements and broader principles set by the FX Global Code.

Box 3. Continued.

More recently, central banks have joined forces with regulated financial institutions in Project Agorá to build on the unified ledger concept proposed by the BIS (BIS (2024)). The project combines tokenised commercial bank money for payments and tokenised central bank money for settlement on the same programmable platform. This could enhance the functioning of the monetary system and provide new solutions using smart contracts and programmability while maintaining its two-tier structure. Agorá builds on the correspondent banking models, which is feasible and legally possible today. This major public-private partnership will seek to overcome several technological, legal and regulatory inefficiencies in how payments happen today. This includes more efficient pre-screening and techniques to improve the exchange of information for AML and CFT compliance checks (Garratt et al (2024)).

Project Mandala is focused on developing a compliance-by-design architecture that could enable a more efficient cross-border transfer of any digital assets, including CBDCs, tokenised deposits and legacy payment systems.

Other BISIH projects on tokenisation are looking at the future of sovereign financial market instruments, and assets in the context of green finance and trade finance. Project Promissa aims to build a proof of concept of a platform for digital tokenised promissory notes. While the project aims to simplify the management of promissory notes between member nations and international financial institutions, it could be extended to include payments (or encashments) associated with such notes by integrating tokenised payment systems based on private or public money. On green finance, Project Genesis 1.0 prototyped tokenised retail green bond platforms and Project Genesis 2.0 prototyped smart contract-based carbon forwards attached to a green bond. The use of blockchain and internet-of-things devices provided real-time transparency on the environmental impact of the green bond and the issuance status of the carbon credit. Project Dynamo showed that programmable and transferable tokens might help address some of the financing challenges faced by small and medium enterprises in supply chains. These digital trade tokens could be programmed with various conditions, including time conditions (eg payment can only be effected on a certain date), action-based conditions (eg payment can only be effected once an electronic bill of lading is issued) and, on the even more creative end, environmental, social and governance (ESG) conditions (eg a premium will be paid if the upstream supplier meets certain ESG conditions).

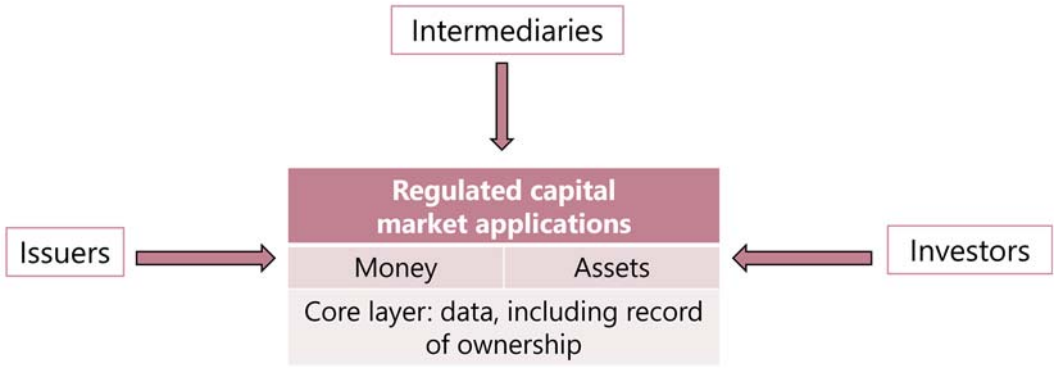
3.3 Market power and network effects

By reducing frictions, platforms may lead to a better matching of supply and demand, and as such may be better able to scale than systems that are not platform-based. Token arrangements, like all payment and settlement systems, exhibit strong network effects, in the sense that each additional investor increases the value of the network for existing investors (so-called direct network effects), and the value of the network for issuers and application developers (so-called indirect network effects). The future development of token arrangements therefore depends strongly on their potential to scale regarding participation but also the ability to process large numbers of transactions. Due to high fixed setup costs, payment networks often require a minimum number, or "critical mass", of users and transactions such that the revenues generated by the network exceed its operating costs. Figure 3 shows a hypothetical stylised platform model of regulated financial market activity, where the issuance, recording and transfer of claims takes place on the same platform.

This platform-based market structure is not new. Since the early 1970s, the information technology revolution has provided the foundation for the emergence of a digital platform economy. Such platforms can facilitate many aspects of modern life, such as communication and marketplaces, which have had a profound impact on economic activity (Acs et al (2021)). A notable example is the smartphone, which enables a multitude of applications to perform functions from telecommunications to personal finance and banking, facilitated by technologies such as an operating system and hardware. Credit cards are an early example of the use of platforms in payments, which has spurred the analysis of platform competition in two-sided markets, subject to network effects between both sides of the market (Rochet and Tirole (2003)). These strong network effects often produce concentration in financial services and

infrastructure provision. This concentration may be intensified if token arrangements combine more functions.

Figure 3. A stylised platform model of regulated financial market applications



4 Risks and challenges

Conventional financial markets handle significant transaction volumes and trade values. The proper execution of trades is therefore a key concern for the parties that participate directly in each trade, and also due to possible knock-on effects for other participants and the broader economy. The same argument holds for platforms that facilitate financial market functions for tokenised assets.

Token arrangements may present some risk mitigation benefits, as discussed in Section 3. However, they may also introduce similar risks as conventional payment, clearing and settlement arrangements and will need similarly strong risk management. These risks may also materialise in a different form due to the notable features of token arrangements, as discussed in Section 4.1. At the same time, within platforms, products, participants and functions are combined in new ways, raising new challenges for risk management and meeting regulatory requirements. Section 4.2 discusses specific challenges related to the integration of functions within platforms and interoperability between platforms.

4.1 Risks

Legal certainty

Legal risk arises from the unexpected or uncertain application of a law. With respect to token arrangements, it could arise in cases where the application of existing laws to the concept of tokens is not clear or certain. For example, in the US, repo transactions receive an automatic stay from bankruptcy, an advantage that may not extend to tokenised versions of repo transactions. Moreover, the legal and regulatory status of a tokenised asset may differ across jurisdictions, particularly as some jurisdictions may adopt token-specific legal frameworks while others apply existing legal frameworks. For example, questions may arise as to whether certain tokenised assets reflect a legal claim or property right; and whether this legal status is consistent with the status of these assets when not in tokenised form. Such issues of legal treatment will be especially relevant in cases of default or insolvency. To the extent that tokenised arrangements alter cross-border transactions, ensuring that infrastructures and financial service providers have a clear, enforceable legal basis for all operations in all relevant jurisdictions may be complex.

Settlement risk

Settlement finality is the legally defined moment at which the transfer of an asset or financial instrument, or the discharge of an obligation, is irrevocable and unconditional and not susceptible to being unwound following the bankruptcy or insolvency of a participant (CPMI (2017)). Depending on the technology and other design choices, operational transfer and final settlement may not coincide in token arrangements, which may lead to settlement risk.[21]

Credit and liquidity risk

Credit risk arises when a counterparty, whether a participant or other entity, will be unable to fully meet its financial obligations when due, or at any time in the future. Token arrangements are not immune from many traditional sources of credit risk, and their structures may introduce new sources. For example, in token arrangements, credit risk may arise with respect to delivery of a (settlement) token or a mismatch between the token and its underlying asset putting its value at question. Such a mismatch could occur when the underlying assets are missing or only partly available, or in cases of costs or limits related to redeemability.

Liquidity risk arises when a counterparty will have insufficient funds to meet its financial obligations as and when expected, although it may be able to do so in the future. Token arrangements may be exposed to liquidity risk in several ways. First, they may be designed with shorter settlement cycles compared with current market conventions for the same asset class (see Section 3). In the extreme, instant trading and settlement requires pre-funding, thus implying a potentially significant increase in liquidity costs. Second, tokens can be programmed to execute transactions when certain conditions are met, which is a way to prevent credit risk but could potentially trigger highly correlated movement of funds, thus creating correlated liquidity risks.[22] Finally, tokenised systems may pose liquidity challenges related to the speed at which users can convert tokenised assets into their non-tokenised forms, potentially draining liquidity from the arrangement.

Governance challenges

Developing effective governance arrangements may be difficult, depending on the breadth and complexity of entities and functions included in a platform. In some cases, the governance of the operations of a token arrangement may – depending on its design and regulatory constraints – involve multiple entities potentially distributed across different jurisdictions or operating different functions. Agreement on eg the technology, issues related to privacy, security, maintenance and settlement might be difficult to achieve. Questions may arise as to which entities may assume primary responsibility and accountability for the operation of the arrangement in case of adverse circumstances. More generally, identifying and managing conflicts of interest, as well as setting risk appetites, may be particularly challenging given the diversity of potential interests and activities. Similarly, ensuring there is suitable expertise within governance arrangements to cover the full scope of operations will be necessary.

Likewise, access policies may differ from traditional systems, conditional on regulatory and other constraints. Access to critical parts of token arrangements could pose risks to the proper functioning of the system, and potential losses to individual participants may have spillover effects to the arrangement as a whole.

[21] For instance, if an operational transfer on the ledger and legal finality do not coincide, the state of a transaction on the ledger could be retroactively reversed eg through legal actions. This could lead to settlement risk.

[22] At the same time, mechanisms do exist in conventional systems that could be replicated in token arrangements to limit liquidity risk, such as auto-collateralisation.

Operational and cyber risk

Operational risk is the risk that deficiencies in information systems or internal processes, human errors, management failures or disruptions from external events will result in the reduction, deterioration or breakdown of services. This risk can take several forms; custody risk, investment risk and cyber risk may be considered the most relevant for token arrangements.

For token arrangements, one of the ways in which operational risk may materialise is through the technological environment. For example, by facilitating the combination of automated processes across different applications, operational disruptions can potentially have an impact on multiple processes simultaneously, possibly in new or unexpected ways. Some arrangements may allow for the use of programs that self-execute automatically when certain conditions are met. These programs may introduce errors into the arrangement that could lead to a wide range of implications, including potential theft or exploitation, data corruption or system availability issues.

Cyber risk is a subset of operational risk and could materialise in different ways, depending on specific design choices. For example, cyber risk may play out differently and in unexpected ways for the use of proprietary versus open source software, due to the different roles that insiders and outsiders play in accessing and programming the platform and the tokens. These risks may increase when there is widespread reliance by participants on the same programs.

More generally, each component of a token arrangement is based on complex and rapidly evolving technologies that require heavily specialised knowledge to be developed and maintained. In addition to the operational risks that manifest within the arrangement, potential operational connections between token arrangements (and between these arrangements and other systems) may introduce new points of vulnerability.

Custody and investment risk

Custody risk is the risk of loss on assets held in custody in the event of a custodian's insolvency, negligence, fraud, poor administration or inadequate record-keeping. For tokenised assets, custody risk may therefore apply to both the token and any underlying assets. Insofar as assets are held off-chain, conventional custody risk applies. Insofar as the assets are held on-chain, custody risks are specific to the technology and custody policies of the platform.

Investment risk is the risk of loss faced by an arrangement when it invests its own or its participants' resources, such as collateral. For token arrangements, this risk will generally be similar to conventional FMIs. For example, investment risk will be influenced by the investment policies of the arrangement, and considerations related to the technology, eg for arrangements that specialise in on-chain collateral management.

4.2 Challenges due to integration and interoperability

In addition to conventional risks, tokenisation may lead to additional considerations that arise from the notable features of token arrangements. This section discusses challenges that may arise due to the vertical integration of functions within platforms, the horizontal interoperability between platforms, and settlement asset options.

Integration of financial market functions

Token arrangements may make combining multiple financial market functions within a common arrangement more operationally feasible (Section 2). This may be associated with the alteration of current market structures and changes to intermediation practices, potentially including functions carried out by entities offering trading, clearing and settlement infrastructures. If such changes eliminate or compromise economically or socially useful functions, such as safeguarding underlying assets or claims, then risks could

be left unaddressed, or unmanageable conflicts of interest may arise, eg when actors trade on their own account and settle their own transactions as well as transactions of other participants.[23]

On the one hand, token arrangements that offer multiple functions and/or asset types, such as within a programmable platform, are more likely to achieve greater efficiency improvements (Section 3). Such arrangements benefit from economies of scope and scale. On the other hand, these effects have the potential to lead to concentration of activity in one or a few arrangements. In the extreme, this may lead to a monopolistic token arrangement with a high degree of market power, posing significant concentration risk, depending on the ownership of the platform.

Interoperability between platforms

On the one hand, tokenisation may facilitate standardisation and therefore interoperability. But on the other hand, the development of multiple arrangements in parallel may lead to siloed arrangements that are not necessarily interoperable with each other. There are several reasons why fragmentation may emerge:

- The arrangement operators may try to achieve dominant positions for their platform, and therefore lack incentives to become horizontally interoperable (BIS (2020)).
- Participants may want to leverage their existing systems, messaging implementations and processes to connect to the arrangements, to minimise investment costs and/or reduce the risk of technical obsolescence (SWIFT (2024)).
- Differences in legal and regulatory regimes – including for tokenised settlement assets – may lead to different implementations across jurisdictions.

Fragmented implementation, in turn, may hinder full materialisation of the opportunities of tokenisation, discussed in Section 3, while increasing risks:

- Arrangements with market power that are not interoperable may translate efficiency gains into higher profits, instead of lower transaction costs.
- A multitude of platforms that use different settlement assets and operating standards may lead to locking-up of liquidity and securities across several platforms.
- Fragmentation creates a need for bilateral connections, which may increase complexity and pose several challenges similar to those faced by existing systems (eg longer transaction chains, higher transaction costs and the emergence of dominant intermediaries that can make the necessary connections).

5 Considerations regarding central banks' policies

Policy choices by central banks will influence whether the benefits of token arrangements will materialise, and risks will be mitigated. Such benefits and risks will also be driven by private sector incentives. This section therefore discusses considerations for the policies of central banks in payment systems and monetary policy. Potential implications for financial stability are assessed in a separate report by the FSB (2024).

Considerations regarding market developments

Central banks have a mandate to promote safe, efficient and accessible payment systems. This includes improving existing systems and assessing the opportunities of technological innovation to prepare for the

[23] See IOSCO (2023).

future of the financial system. In this context, a primary consideration for central banks is therefore how to respond to the market developments regarding token arrangements. The potential role of the central bank with respect to token arrangements and the timing of their potential involvement may differ across jurisdictions. It could involve a range of activities, among them: public-private cooperation, including its potential role as an operator of the payment system and a provider of the settlement asset; convening stakeholders to foster dialogue, coordinate collaboration and avoid fragmentation; and conducting supervision and regulation along with other relevant authorities domestically and internationally.

Central banks may wish to coordinate tokenisation efforts, especially where private initiatives operate in silos, serving only their own customers, and hence do not capture the full network effects of larger-scale operations. To eventually capture the full potential benefits of tokenisation, banks are exploring ways to combine their tokenisation efforts and to connect to other parts of the financial system.[24] The BIS, in cooperation with seven central banks and dozens of commercial banks, are exploring tokenisation of cross-border payments in Project Agorá. This follows earlier work by the BIS that considers DvP and PvP arrangements using tokenised central bank money and tokenised assets (eg Project Helvetia and Project Jura). Central banks are involved in these projects not only as coordinators, but also as operators of payment systems and providers of the settlement asset. Central banks' involvement could help to reduce the likelihood that potentially high-value tokenisation initiatives that originate at individual banks stay siloed and stagnate.

Central bank involvement at an early stage may be useful to assess the trade-offs arising from "winner takes most" effects, which are common in payment and settlement systems. On the one hand, where switching costs are high, due for instance to a lack of competition among token arrangements, lower transaction costs for intermediaries may not translate into lower costs for users, but rather into higher profit margins for intermediaries. Likewise, once a single platform captures a large market share, it has no incentive to become horizontally interoperable with different token arrangements (see Section 4 and BIS (2020)). On the other hand, the larger a platform's reach, the greater the network effects and potential economies of scale and scope (BIS (2022) and Section 3).

Given the global nature of these developments and potential divergence in technical standards, the international central banking community may wish to foster consistency in approaches by private sector entities to technical aspects of tokenisation. Experience in the field of cross-border payments shows that international standards have not always been implemented in a consistent manner across entities and jurisdictions. This has led to CPMI involvement to promote alignment (CPMI (2023)).

Considerations for settlement assets

Central bank money plays a key role in payment systems and FMIs (CPSS (2003)).[25] It provides the safest and most liquid settlement asset available and is based on a clear institutional framework geared towards public policy objectives. The settlement of transactions between commercial banks and other eligible entities in central bank money supports the "singleness of money". With the singleness of money, monetary exchange is not subject to fluctuating exchange rates between public and private forms of money. The singleness of money is also supported with the robustness of relevant regulatory and supervisory frameworks for those who issue private forms of money. The singleness of money is a crucial

[24] These projects include the Regulated Liability Network (RLN), Global Layer 1 (GL1) and Project Agorá to build on the unified ledger concepts proposed by the BIS (2023a).

[25] Accordingly, central bank money is given a prominent role in payment systems and FMIs by the Principles of Financial Market Infrastructure (the PFMI). Principle 9 (Money Settlements) of the PFMI states that "An FMI should conduct its money settlements in central bank money where practical and available. If central bank money is not used, an FMI should minimise and strictly control the credit and liquidity risk arising from the use of commercial bank money." The PFMI apply to payment systems that are systemically important, as well as central securities depositories, securities settlement systems, central counterparties and trade repositories. All FMIs are encouraged to observe these principles.

factor for a currency to effectively become the primary measure of economic value, or the unit of account, within a modern economy (CPSS (2003)). In sum, the coexistence of central and commercial bank money, convertible at par, provides the backbone of the monetary system (CPSS (2003), BIS (2023a)).

Central banks support the singleness of money by issuing central bank money in the form of deposits at the central bank for use by eligible institutions. In the context of tokenisation, a foundational consideration for central banks is under what circumstances and in what manner they should provide central bank money as a settlement asset for token arrangements. A range of options are available to central banks considering the use of central bank money in token arrangements.[26] One option could be connecting existing central bank payment systems to outside token arrangements. Another option could be providing a tokenised form of central bank money on programmable platforms that are operated by the central bank.[27] A third option could be providing a tokenised form of central bank money on the same multi-asset platforms where tokenised deposits reside. In the third option, by using tokenised central bank money as a settlement asset, payments in tokenised systems can be made the same way they currently are, by using tokenised deposits to update the liability structure of commercial banks and settling exposures generated by these updates with tokenised central bank money. In fact, the updates and interbank settlements could all settle atomically, thus providing the advantages discussed in Section 3.

A pertinent consideration for central banks is whether and how settlement in central bank money could be conducted on third-party platforms that are not owned or operated by the central bank, and what implications this would have in terms of efficiency, governance and allocation of responsibilities, among other things. Further considerations for central banks include:

- What impact could tokenisation have on the demand for specific central bank money forms?
- How would it influence the central bank's issuer and operator function?
- How might central banks respond, and what are the trade-offs between policy options?
- How would these trade-offs change under different scenarios (eg fragmented vs concentrated platforms, changes in the roles of intermediaries)?

The investment trade-offs as discussed in Section 3 may be relevant for central banks in this context.

Despite the current momentum with tokenised deposits,[28] there is continued discussion regarding the use of stablecoins as settlement assets. To date, stablecoins, which are neither central bank nor commercial bank money, have exhibited wide differences in design, especially related to the degree and quality of asset backing. In the stablecoin model, payments are not made by restructuring deposit liabilities across commercial banks and settling resulting interbank exposures in central bank money, but rather by transferring the issuer's liability from one holder to another. This means individuals may end up holding the liabilities of multiple issuers and that issuers do not necessarily know who holds their liabilities. This raises a number of issues (BIS (2023a), Garratt and Shin (2023)). First, stablecoin transactions do not settle using central bank money.[29] Second, stablecoins, as constructed today, are traded assets. They have a secondary market price, and this price may deviate from par. This could create challenges for stablecoin issuers to redeem their stablecoins at par. Third, market participants that settle in central bank or commercial bank money typically have access to credit from those institutions to facilitate settlement. Most stablecoin issuers do not provide credit, and this could affect the speed, cost and efficiency of

[26] See for example Durfee et al (2023), Neuhaus and Plooij (2023), Bank of England (2024), Bank of France (2023), and BIS (2023a, Box B).

[27] Some central banks, such as the Bank of France, began to experiment with wholesale central bank digital currency (CBDC) as early as 2020. The Eurosystem also launched exploratory work with two waves of experiments in 2024 aimed at testing three solutions for making central bank money available, including a CBDC solution, for the settlement of tokenised assets.

[28] See, in addition to the projects mentioned above, the announcement by Partior, which raised $60 million in series B funding to explore tokenisation efforts.

[29] Settlement in central bank money could occur only when stablecoins are redeemed for cash or commercial bank deposits.

settlement (Bolt et al (2024)). Finally, there is also a concern that, due to the materialisation of network effects, dependence on a single or a few stablecoin issuers may lead to a concentration of risk.

Going forward, central banks may further consider their policy response to stablecoins. While some have articulated opposition to the stablecoin model (BIS (2023a)), globally the debate continues. The inherent risks, and the materialisation of risks in the recent years, contributed to international policy and standard-setting work on guidance and recommendations for systemically important stablecoin arrangements (eg CPMI-IOSCO (2022) and FSB (2023)).[30] National authorities have also taken steps to address the risks associated with the issuance of stablecoins and continue to consider ways in which to address the risks, and regulatory frameworks that are emerging across jurisdictions.[31]

Considerations regarding oversight

Through their oversight function, central banks promote the safety and efficiency of payment, clearing and settlement systems and the broader payments ecosystem. For this role, the emergence of token arrangements raises questions related to monitoring such arrangements (whether planned or already existing), assessing them against the objectives of safety and efficiency, determining whether such arrangements would qualify as FMIs, if so whether they would be systemically important or not, and – where necessary – inducing change.[32] Token arrangements have notable features that may differ from traditional FMIs (Section 4). This underlines the relevance of:

- *Monitoring*. Through their oversight role, central banks may monitor the development of token arrangements, to assess the potential safety and efficiency implications of these arrangements, as well as their impact on the broader payment system and on central bank operations and objectives. Some questions for central banks in this role include: What tools and mechanisms do they have to monitor these developments? What tools does the central bank have to assess these arrangements and, where necessary, induce change? For those token arrangements that are FMIs, are there any notable features that change the central bank's criteria for identifying FMIs that should be subject to their regulation, supervision and oversight? Do those token arrangements present any impediments to carrying out effective oversight? Are they structured in a way to facilitate oversight of the safety and efficiency of the whole arrangement and not just its components?
- *Cooperation*. Cooperation between central banks, and between central banks and other authorities, with respect to token arrangements may be desirable in certain circumstances. Questions with respect to cooperation include whether the central bank has appropriate mechanisms for informing other relevant authorities that may have an interest in token arrangements within its jurisdiction; and how central banks can cooperate to support each other in promoting the safety and efficiency of payment systems given the potential implications from tokenisation.
- *Assessment*. For those token arrangements that are within scope of a central bank's oversight, the central bank may assess whether the arrangement meets relevant policy requirements, taking notable features into consideration that could present safety or efficiency implications, if any.

[30] For example, CPMI-IOSCO (2022) clarifies that a stablecoin used by a systemically important stablecoin arrangement should have little or no credit or liquidity risk.

[31] See Crisanto et al (2024) for an overview.

[32] Central bank oversight of payment and settlement systems (CPSS (2005)).

Considerations regarding monetary policy

The emergence of token arrangements raises questions for monetary policy as well. Central banks rely on safe and efficient payment systems and funding markets to implement monetary policy, and their frameworks are designed to work with the payment and financial ecosystem. Implications for the implementation of monetary policy would depend on the scale at which these arrangements are adopted and by the specific markets of operation. Although outcomes are uncertain, they could work through three possible channels: (i) monetary policy implementation; (ii) the use of tokenised forms of money; and/or (iii) changes to the market structure[33] due to the emergence of token arrangements.

First, the rules and standards of token arrangements, such as operating hours, value date rules or access policies of token arrangements, may differ from existing systems in some jurisdictions, and may affect the operational implementation of monetary policy by central banks.[34] Second, the use of tokenised money may change the aggregate levels of issuance of public and private money, and would have uncertain effects on the demand for central bank money. Third, token arrangements could imply changes to the market structure eg through integration of functions and the degree of interoperability versus fragmentation between platforms (Sections 3 and 4). Any such changes to the structure of funding markets that are critical for the implementation of monetary policy create implications for central banks. For example, should greater automation influence demand, volatility or liquidity in critical asset markets, policy implementation and the transmission mechanism could be affected.

6 Conclusion

The Brazilian G20 Presidency has asked the BIS and the CPMI to examine the meaning of tokenisation in the context of money and other assets, and how to envision a tokenised environment that builds on the best attributes of the current monetary and financial system, while discussing potential future implications. This report is the result of that investigation. Its main findings are the following.

First, to understand the meaning of tokenisation in the context of money and other assets, it is useful to view it as part of a longer-term evolution in market structures. This report uses the term *token arrangement* to indicate the infrastructure that supports the use of digital tokens in financial transactions. The main finding is that these arrangements that provide platform-based intermediation across the end-to-end life cycle of financial assets may lead to changes in market structure. While platform-based intermediation is not new in the financial sector, tokenisation can be regarded as an innovation relative to existing arrangements, since token arrangements potentially enable multi-asset, multi-function and multi-party financial services to take place on the same platform. As in other industries, platform-based financial intermediation may lead to network effects, reduce transaction costs, open up the market for transactions that were not previously feasible due to high information or operational costs, and improve the allocation of resources.

Second, tokenisation may affect how pre- and post-trade functions are executed for money and other assets. It offers opportunities for market participants in terms of safety (for example, through the expanded use of PvP and DvP settlement, thus reducing principal risks) and increasing efficiency (eg due to built-in programmability and composability of transactions, and process automation and data reconciliation within a shared ledger).

[33] For example, the possible impact of the use of tokenised forms of money on the relative importance of central bank and commercial bank money in a nation's payment system and the two-tier banking system.

[34] From a legal point of view, the eligibility of tokenised assets as monetary policy collateral could also be affected, even though they may be issued on platforms operated by various private players and have specific characteristics.

Third, while the potential benefits of tokenisation have attracted interest, as reflected in investment by private sector market participants and experimentation by public authorities, the costs and risks also need to be taken into account. Such investment costs are likely to be higher for tokenisation initiatives with higher expected benefits. Case by case assessments are needed to determine whether existing or token arrangements would be more efficient and safer. Additionally, the regulatory framework is under development in different jurisdictions, and it will take time for network effects to play out.

Fourth, risks that apply to conventional market infrastructures also apply to token arrangements, such as governance, legal, credit and liquidity risks, or custody and operational risks. Such risks may materialise in a different manner due to the notable features of tokenisation. For example, risks may arise due to the separation of the token and the underlying asset, which may give rise to conflicts of interest, and to the governance costs of developing, operating and maintaining shared ledgers. Additional challenges arise due to the integration of functions within platforms, which may further introduce conflicts of interest. Moreover, market participants may lack incentives to create interoperability between platforms, due to network effects and incentives to gain market power.

Looking forward, tokenisation may have implications for the roles of central banks in payments, monetary policy and financial stability (on the third, see FSB (2024)). A primary consideration for central banks is whether, and to what extent, to react to ongoing private sector tokenisation initiatives. For example, central banks could consider ways to foster interoperability if markets develop in a fragmented manner. A second consideration is whether and how central banks assess the trade-offs and the appropriate balance between different types of settlement assets in token arrangements. This may include how or in what form central banks could provide central bank money as a settlement asset for token arrangements. A third consideration concerns identifying token arrangements that may already, or potentially in the future, meet the criteria to be subject to regulation, supervision and oversight at the individual jurisdiction level. They might also be subject to international standards such as the PFMI. Relevant authorities might consider how to cooperate, both within and across jurisdictions. A final consideration relates to the potential impact of token arrangements on monetary policy implementation, for example through changes in the structure of regulated markets or the demand for central bank versus other types of money.

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Annex 1: Glossary

Access: As used in this report, this can mean the access of households and businesses to payment services and the ability to use the services of a CBDC system by banks, other payment service providers and, where relevant, other market infrastructures.

Application programming interface (API): a set of rules and specifications for software programs to communicate with each other, which forms an interface between different programs to facilitate their interaction. See www.bis.org/bcbs/publ/d486.pdf.

Atomic settlement: all legs of a transaction are executed or none of them are executed.

Central bank digital currency (CBDC): central bank money in a digital format, denominated in the national unit of account, that is a direct liability of the central bank and can be used for retail payments and/or wholesale settlement. See www.bis.org/publ/arpdf/ar2021e3.pdf

Central bank money: A central bank which can be used for settlement purposes. The widespread use of central bank money for large and critical settlements is pivotal to the functioning of the global financial system, offering safety, availability, efficiency, neutrality and finality. See www.bis.org/cpmi/publ/d101a.pdf.

Clearing: The process of transmitting, reconciling and, in some cases, confirming transactions prior to settlement, potentially including the netting of transactions and the establishment of final positions for settlement. See www.bis.org/cpmi/publ/d101a.pdf.

Closed loop: Payment system that provides services directly to both payers and payees. Sometimes known as an in-house or intragroup transfer system.

Credit risk: The risk that a counterparty, whether a participant or other entity, will be unable to meet fully its financial obligations when due, or at any time in the future. See www.bis.org/cpmi/publ/d101a.pdf.

Cross-border and cross-currency payments: Cross-border payments are payments where the payment service providers of the payer and payee reside in different jurisdictions. Many, but not all, of these are also cross-currency payments – that is, payments where the payer and payee are respectively debited and credited in different currencies. Payments within monetary unions or in a common invoice currency may be cross-border but not cross-currency. See www.bis.org/publ/qtrpdf/r_qt2003h.htm.

Delivery versus payment (DvP): the settlement mechanism that links a securities transfer and a funds transfer so that delivery occurs if and only if the corresponding funds transfer occurs. See www.bis.org/cpmi/publ/d101a.pdf.

Deposits: liabilities held at a financial institution that are used to settle transactions within payment and settlement systems.

Distributed ledger technology (DLT): the processes and related technologies that enable nodes in a network (or arrangement) to securely propose, validate and record state changes (or updates) to a synchronised ledger that is distributed across the network's nodes. In the context of payment, clearing and settlement, DLT enables entities, through the use of established procedures and protocols, to carry

out transactions without necessarily relying on a central authority to maintain a single "golden copy" of the ledger. See www.bis.org/cpmi/publ/d157.pdf.

Financial market infrastructure (FMI): a multilateral system among participating institutions, including the operator of the system, used for the purposes of clearing, settling or recording payments, securities, derivatives or other financial transactions. See www.bis.org/cpmi/publ/d101a.pdf.

Fragmented and truncated data formats: Data standards and formats vary significantly across jurisdictions, infrastructures and message networks and the amount of data that is carried in most cross-border messages is extremely limited. This prevents high rates of automated "straight-through processing" and leads to delays in processing and releasing cross-border payments and increases technology and staffing costs.
See https://www.fsb.org/wp-content/uploads/P090420-1.pdf

Interoperability: the technical, semantic and business compatibility that enables a system or mechanism to be used in conjunction with other systems. Interoperability allows participants in different systems to conduct, clear and settle payments or financial transactions across systems without participating in multiple systems. See www.bis.org/publ/bisbull49.pdf.

Ledger: a recording information technology. 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. See www.bis.org/publ/bisbull72.pdf.

Payment versus payment (PvP): A settlement mechanism that ensures that the final transfer of a payment in one currency occurs if and only if the final transfer of a payment in another currency or currencies takes place. See www.bis.org/cpmi/publ/d101.htm.

Legal risk: the risk of the unexpected or uncertain application of a law or regulation, usually resulting in a loss. See www.bis.org/cpmi/publ/d101a.pdf.

Liquidity risk: the risk that a counterparty, whether a participant or other entity, will have insufficient funds to meet its financial obligations as and when expected, although it may be able to do so in the future. See www.bis.org/cpmi/publ/d101a.pdf.

Programmable platform: the technologies that allow eligible participants to develop and execute applications that update a common ledger

Retail CBDC (rCBDC): A CBDC for use by the general public.
See https://www.bis.org/publ/arpdf/ar2021e3.pdf

Settlement: the discharge of an obligation in accordance with the terms of the underlying contract. See www.bis.org/cpmi/publ/d101.htm.

Settlement account: an account containing money and/or assets held with a central bank, central securities depository, central counterparty or any other institution acting as a settlement agent, which is used to settle transactions between participants or members of a commercial settlement system. See www.bis.org/cpmi/publ/d101.htm.

Settlement asset: an asset used for the discharge of obligations as specified by the rules, regulations or customary practice for a financial market infrastructure. See www.bis.org/cpmi/publ/d101.htm.

Settlement finality: the point at which the irrevocable and unconditional transfer of an asset occurs. Final settlement is a legally defined moment. See www.bis.org/cpmi/publ/d101.htm.

Smart contract: protocol or code that self-executes when certain conditions are met. See www.bis.org/publ/qtrpdf/r_qt2003i.pdf.

Stablecoin: a cryptoasset that aims to maintain a stable value relative to a specified asset, or a pool or basket of assets. See www.fsb.org/wp-content/uploads/P131020-3.pdf.

Token: a representation of something else. In the context of money and other financial assets, digital tokens are entries in a database that are recorded digitally and that can contain information and functionality within the token themselves. See www.bis.org/publ/arpdf/ar2023e3.pdf.

Tokenisation: the process of generating and recording a digital representation of traditional assets on a programmable platform.

Token arrangement: the programmable platforms and/or participating entities that enable financial market functions by utilising digital tokens. See www.bis.org/cpmi/publ/d190.pdf.

Wallet: electronic wallets are payment arrangements that enable end users to securely access, manage and use a variety of payment instruments issued by one or more payment service providers via an application or a website. The electronic wallet may reside on a device owned by the holder, eg a smartphone or a personal computer, or may be remotely hosted on a server but is under the control of the holder. See www.bis.org/cpmi/publ/d191.pdf.

Wholesale CBDC (wCBDC): a CBDC for use by financial institutions (wholesale transactions) that is different from balances in traditional bank reserves or settlement accounts. See www.bis.org/publ/arpdf/ar2021e3.pdf.

Annex 2: Acronyms and abbreviations

AML	anti-money laundering
API	application programming interface
BIS	Bank for International Settlements
BISIH	BIS Innovation Hub
CCP	central counterparty
CFT	combating the financing of terrorism
CBDC	central bank digital currency
CPMI	Committee on Payments and Market Infrastructures
CPSS	Committee on Payments and Settlement Systems
CSD	central securities depository
DLT	distributed ledger technology
DvP	delivery versus payment
FMI	financial market infrastructure
FoP	CPMI Future of Payments Working Group
FSB	Financial Stability Board
FX	foreign exchange
GFMA	Global Financial Markets Association
G20	Group of Twenty
IMF	International Monetary Fund
IOSCO	International Organization of Securities Commissions
ISO	International Organisation for Standardisation
PSP	payment service provider
PvP	payment versus payment
PFMI	principles for financial markets infrastructures
RTGS	real-time gross settlement
SSS	securities settlement system
wCBDC	wholesale central bank digital currency

Annex 3: Composition of the Future of Payments Working Group (FoP)

Chair

Board of Governors of the Federal Reserve System	David Mills

Members

Central Bank of Argentina	Luis d'Orio
Reserve Bank of Australia	Chris Thompson
	Cameron Dark
National Bank of Belgium	Filip Caron
Central Bank of Brazil	Lucio Oliveira
	Daniel Tavares de Castro
Bank of Canada	Peter Youngman
	Scott Hendry
People's Bank of China	Changchun Mu
	Lyu Yuan
European Central Bank	Andrea Pinna
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Bank of France	Claudine Hurman
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	Enrica Detto
Bank of Japan	Naoto Shimoda
	Yuko Morikawa
Bank of Korea	Duckhyung Kim
	Jeamin Ryu
De Nederlandsche Bank	Vera Lubbersen
	Marc van der Maarel
Saudi Central Bank	Mohsen Al-Zahrani
	Khalid Alotaibi

Monetary Authority of Singapore	Tze Hon Lau
	Ryan Chan-Wei
South African Reserve Bank	Annah Masoga
	Pearl Malumane
Bank of Spain	Sergio Gorjon
Sveriges Riksbank	Kristian Jönsson
Swiss National Bank	Benjamin Müller*
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Central Bank of the Republic of Türkiye	Büşra Ercan
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International Monetary Fund	Tommaso Mancini Griffoli
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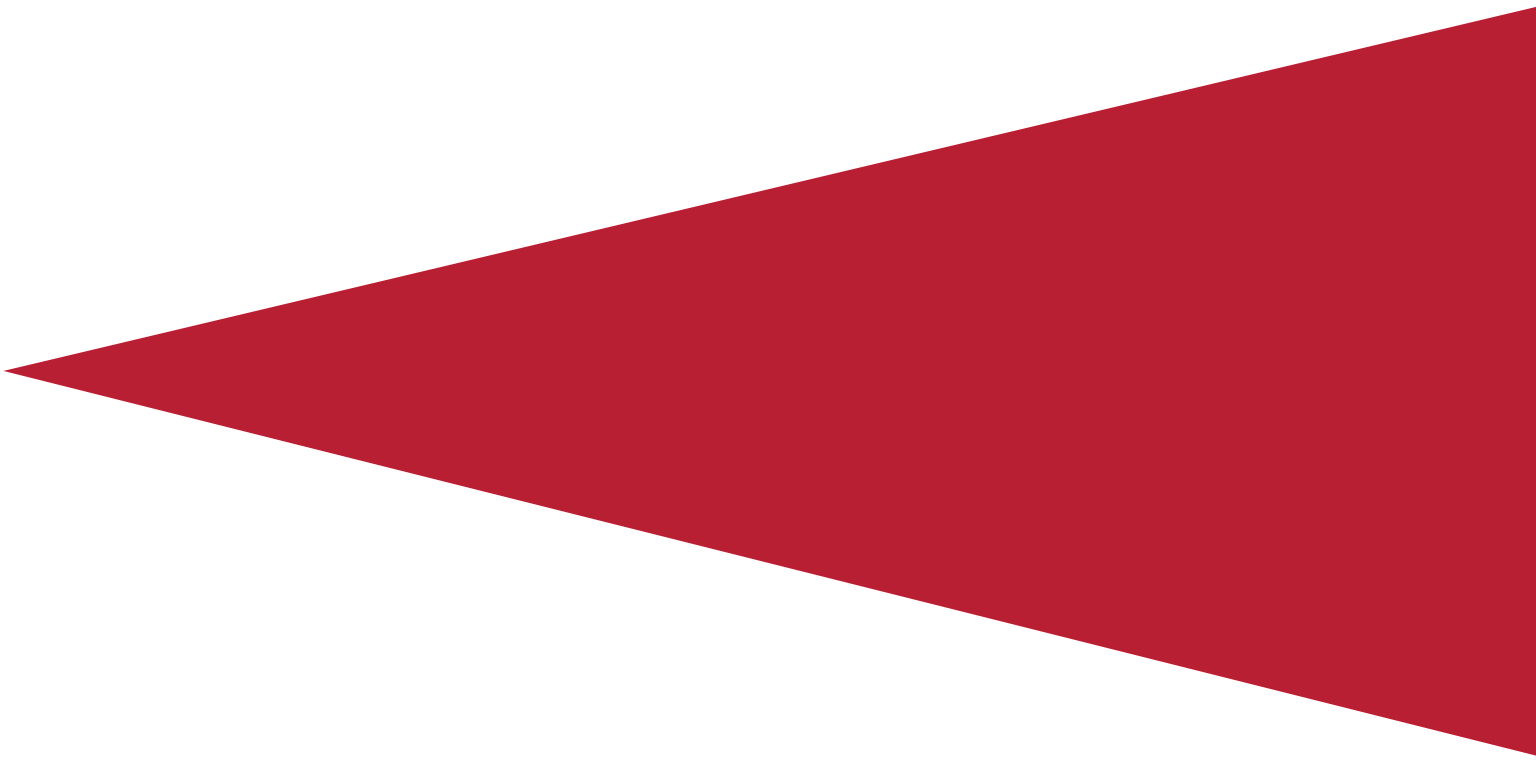
Promoting global monetary and financial stability



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