TOKENISATION OF ASSETS AND DISTRIBUTED LEDGER TECHNOLOGIES IN FINANCIAL MARKETS

Potential impediments to market development and policy implications

OECD Business and Finance Policy Papers, No. 75

OECD

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Market participants and policy makers have shown strong interest in DLT-based financial applications such as tokenisation. However, despite growing enthusiasm by market participants and the emergence of a clearer divide between crypto-assets and regulated tokenised assets, adoption of tokenisation remains scarce. This paper analyses possible reasons for the absence of a market for tokenised assets and puts forward policy considerations for financial supervisors and policy makers.

This paper is part of the series "OECD Business and Finance Policy Papers" https://doi.org/10.1787/bf84ff64-en.

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Foreword

This paper provides an update to earlier OECD work on tokenisation of assets, examines potential benefits, risks and market trends around tokenisation; discusses potential impediments to the development of a market for such assets; and considers policy implications.

The paper has been developed by the Capital Markets and Financial Institutions of the OECD Directorate for Financial and Enterprise Affairs. It was prepared by Iota Kaousar Nassr under the supervision of Fatos Koc, Head of the Financial Markets Unit, and Serdar Çelik, Head of Division.

The paper supports the work of the OECD Committee on Financial Markets. and was discussed by the Committee in May 2024 and October 2024. It was approved for release by the Committee on 16 December 2024.

The author gratefully acknowledges valuable input and feedback provided by the following individuals and organisations: Nicolas Barbaroux, Banque de France; James Chapman, Bank of Canada; Anne Chone, European Securities and Markets Authority; Adam Głogowski and Pawel Gasiorowski, National Bank of Poland; Daniela Gariboldi, Commissione Nazionale per le Societa e la Borsa (CONSOB); Giuseppe Grande and Ilaria Supino, Banca d'Italia; Eleftheria Kostika, Bank of Greece; Sylvie Golay Markovich and Laura Felber, Swiss National Bank; Ariane Meunier, FOD Financiën - SPF Finances Belgium; Fayyaz Muneer, Tom Duggan and Dylan Cunningham, HM Treasury; Borut Poljšak, Bank of Slovenia; Paull Randt and Irina Leonova, US Treasury; María Antonieta Campa Rojas, Banco de México; Necmettin Mete Sakallioglu, Ministry of Treasury and Finance, Türkiye; Mai Santamaria and Jefferson Vieira, Department of Finance, Ireland; Ivan Keller and Naisa Baldissera May, European Commission DG FISMA; Kris Nathanail, International Organization of Securities Commissions; Denise Garcia Ocampo, Bank for International Settlements.

Table of contents

FIGURES

BOXES

Executive summary

Distributed ledger technologies (DLTs) could become a transformative feature of financial markets, both in financial products and in the underlying market infrastructure. The tokenisation of assets, involving the digital representation of real assets on distributed ledgers (digital twins) or the issuance of traditional asset classes in tokenised form (native tokens), excluding crypto-assets, is a core part of this technology's revolutionary potential (OECD, 2020[1]). A possible proliferation of the use of DLTs and tokenisation in financial markets could affect core financial market activities, such as trading, pricing and liquidity of securities, processes such as clearing and settlement, and activities such as securities lending and borrowing markets.

Although DLT technologies and tokenisation are still at early stages of live deployment in financial markets, market participants have shown renewed interest in these practices as of recent driven *inter alia* by their theoretical benefits (OECD, 2020[1]). These include efficiency gains driven by automation and disintermediation; transparency; improved liquidity potential and tradability of assets with near-absent liquidity; shorter settlement cycles, faster and potentially more efficient clearing and settlement; as well as programmability at the post-trade and beyond.

Discussions and experimentation around tokenisation of deposits and other DLT-based forms of financial products, regulated and compliant stablecoins and possible DLT-based Central Bank Digital Currencies (CBDCs), have contributed to renewed interest in DLT and tokenisation deployments in financial markets. Despite growing momentum in communication by market participants and a clearer divide being drawn between crypto-assets and regulated tokenised assets, adoption of DLT-based finance and tokenisation remains scarce. The vast majority of tokenised transactions have been part of pilots or other experimentation by the private and public sector, in what is today a fragmented environment of pockets of liquid tokenised asset platforms, and with rare live projects reaching meaningful size as of today.

Earlier work of the OECD Committee on Financial Markets in 2019 provided analysis on the impact that a scenario of wide-spread adoption of tokenisation could have, discussing emerging opportunities and risks of the application of DLTs for financial markets and their participants, illustrated through early-stage pilots in OECD and non-OECD economies (OECD, 2020[1]). This paper analyses possible reasons that may explain the absence of a market for tokenised assets, also in light of the absence of empirical evidence of any actual benefits delivered by DLT and tokenisation for markets and their participants. The objective of the paper is to identify, in an analytic manner, some of the obstacles to greater adoption of tokenisation in financial markets, without taking a position on whether public authorities should address these obstacles or how they might do so.

Possible limitations identified in the paper are associated with the lack of liquidity and absence of an ecosystem for tokenised assets; the absence of evidence around measurable materialised benefits at large scale and the lack of investment rationale for the transition towards DLTs; the need for payment rails integrated in DLTs or wholesale CBDCs to exist for the payment leg of settlement; the drawbacks of instant and simultaneous 'atomic' settlement; the lack of custodians to onboard investors and assets; the complexity of the underlying DLT infrastructure; the absence of identification solutions and the lack of industry standardisation practices around tokenisation. Other limitations include legal issues, such as the

fact that ownership of a token does not necessarily accord ownership to the underlying asset; the legal status of smart contracts; or limits with regards to settlement finality when using DLTs.

In terms of regulatory environment, participants in tokenised assets transactions should comply with appropriate regulatory and supervisory requirements in place given the tech-neutral principle adopted by financial regulators in OECD countries, which does not promote or discourage any specific type of technology (same activity, same risk, same regulation) (OECD, 2021[2]). Financial market participants are expected to demonstrate risk management and control process commensurate with whichever technology or platform the institution chooses to use to conduct their activities.

Despite the applicability of existing laws and the potential usefulness of traditional regulatory tools, however, there may be a need to further identify risks that are more acute in DLT-based finance and tokenisation that may warrant additional policy considerations. Financial supervisors in particular may have a role in understanding DLT technology well enough to be able to supervise activities leveraging this technology and conclude on whether risk management practices are sufficient to identify, measure, monitor and control risk.

With the proper foundations in place, new possibilities of potential efficiencies and productivity gains in tokenised assets markets can be brought about in a manner that need not negatively impact financial stability, law enforcement, local and global policy regimes.

1 Tokenisation of assets: Potential benefits and risks, and market adoption

1.1. Potential benefits and risks of tokenisation

The potential benefits of tokenisation of assets and DLT-based finance have been extensively analysed in previous studies (OECD, 2020[1]). These include efficiency gains driven by automation and disintermediation, and associated cost and speed enhancements; transparency; fractionalisation; improved liquidity potential and tradability of assets with near-absent liquidity; faster and potentially more efficient clearing and settlement; as well as programmability at the post-trade and beyond, and associated streamlining of cross-border funds or information flows, enabling "always on" transactions not bound by business hours. Product innovation could also be supported by DLT-based finance particularly leveraging on the data and traceability characteristics of ledgers, for example in case of green bond issuance (e.g. Project Genesis (BIS Hub, 2021[3])). In terms of collateral management, tokenisation could enhance the mobility of collateral, simplify collateral access and posting, and reduce reconciliation costs.

The potential for shorter settlement cycles and the associated reduced demands on liquidity held against settlement risk may also appear attractive. Simultaneous 'atomic' Delivery vs Payment (DvP)[1] or programmable settlement could generate important efficiencies at the post-trade, with efficiencies also throughout the lifecycle of tokenised transactions (e.g. instant transfers of asset ownership rights; automated asset servicing). A potential take-off in tokenisation could also affect repo activity for the funding of positions, as well as securities lending activities used as part of trading strategies, given the need to pre-fund positions in tokenised transactions, but also allowing for greater mobility and unwinding of collateral and easier mobilisation of collateral across security pools (OECD, 2020[1]).

New financial services or products could also be enabled by tokenisation and DLT-based finance, centred around use of automated self-executing code in the form of smart contracts. One example involves the possible use of liquidity pools or automated market makers (AMMs) for the trading of tokenised assets (OECD, 2022[4]; OECD, 2022[5]). The introduction of such so-called 'decentralised finance' (DeFi) technologies in traditional financial markets in a compliant manner is indeed being tested in pilots (e.g. BIS Hubs Projects Guardian and Marianna).

Similar analysis on the potential risks of a proliferation of asset tokenisation has been previously discussed and continues to be analysed in light of numerous emerging pilots and with a focus on possible implications for financial stability (Carapella et al., 2023[6]; FSB, 2024[7]). Major potential risks include technology-related and operational ones (scalability; settlement finality; lack of interoperability; network stability; cyber-risks); governance risks (accountability; control and validations; identification-related issues); data protection and privacy issues; as well as issues pertaining to ownership rights and to the legal status of smart contracts (OECD, 2020[1]).

A potential proliferation of tokenisation in the financial markets and the associated disintermediation could affect trading by disrupting the market-making model, which could in turn affect volatility and liquidity of related markets, especially in times of stress. When it comes to liquidity, tokenisation could be a double-edged sword with potential positive effect on less-liquid assets (e.g. private debt) under a number of conditions that need to be fulfilled; but also potential risks of bifurcation of liquidity between on-chain and off-chain markets for the same asset, potentially drying up liquidity in the off-chain markets and giving rise to risks of arbitrage (OECD, 2020[1]). Similarly, in terms of pricing of the assets, tokenisation could enhance transparency regarding transactional data and information around the issuer and the asset characteristics given the ledger character of DLTs, thus improving price discovery, but also holds important risks that trading of tokenised assets risks becomes fragmented if the asset trades on non-interoperable networks and exchanges on- and off-the chain, especially for 'real world assets' that continue to exist off-chain (digital twins). That, in turn, could lead to fragmentation of the markets on which the token trades and of the corresponding pricing, while it may also result in the delinking of the token's price from the price of the underlying asset in conventional markets for assets existing off-chain (OECD, 2020[1]).

In terms of financial stability implications, given the small scale of tokenisation activity, it does not currently pose a material risk to financial stability (FSB, 2024[8]). Nevertheless, analysis by the Financial Stability Board identifies several financial stability vulnerabilities associated with DLT-based tokenisation, which relate to liquidity and maturity mismatch; leverage; asset price and quality; interconnectedness; and operational fragilities. These could arise if the tokenised part of the financial system scales up significantly, if increased complexity and opacity of tokenisation projects lead to unpredictable outcomes in times of stress, and if identified vulnerabilities are not adequately addressed through oversight, regulation, supervision, and enforcement (FSB, 2024[8]).

1.2. The absence of a market for tokenised assets

Despite a plethora of potential benefits, and notwithstanding the growing momentum in communication by market participants and the clearer divide being drawn between crypto-assets and regulated tokenised assets, adoption of tokenisation and DLT-based finance remains scarce. The vast majority of tokenised transactions are part of pilots or other experimentation by the private and public sector (e.g. proofs-of-concept or sandboxes, see Box 2 for an example), with few private-led live projects developed by financial institutions to service primarily their own clientele in a fragmented manner, without interoperability, thus not reaching meaningful size as of today.

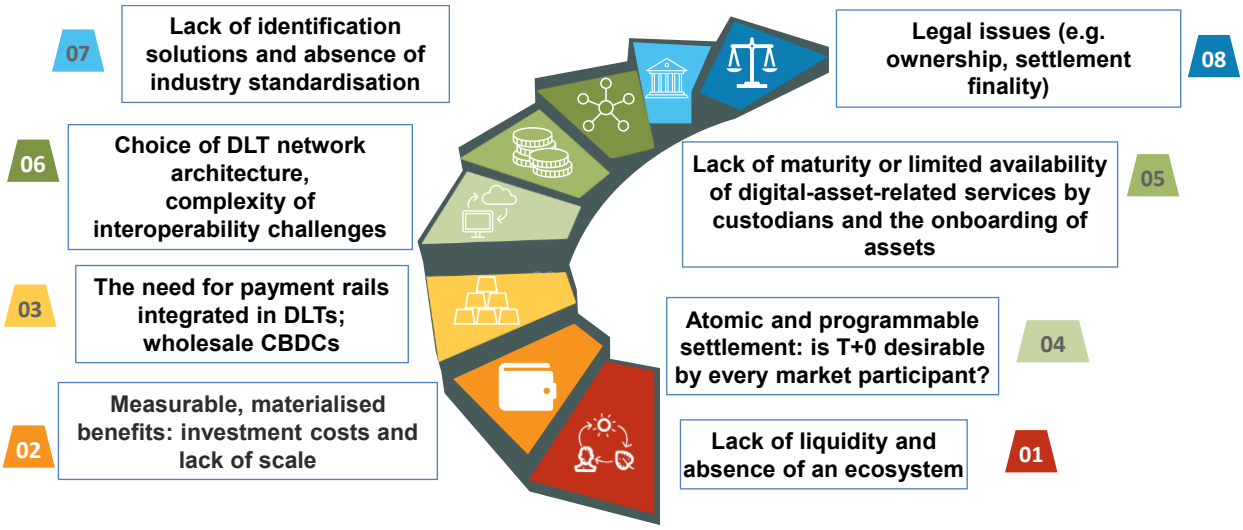
Some of these initiatives include products that support tokenised intraday repo transactions for banks; products that enable the tokenisation of shares of money market funds for posting as collateral to support repos; the use of tokenised deposits; and trade solutions that would leverage smart contract-based bank guarantees. That said, there are currently limited comprehensive and consistent public data available around tokenisation activity, including around the market share of different types of token types and their underlying assets.

It is also important to note that the pace and timing of tokenisation adoption varies across asset classes, and that different drivers may influence (positively or negatively) different forms of tokenisation to varying degrees. Indeed, it is reasonable to expect tokenisation adoption to follow heterogeneous paths and progress at different pace across asset classes.

2 Possible reasons for the absence of a market for tokenised assets

There are several hypotheses to explain the absence of a market for tokenised assets at current stage (see Figure 1); their analysis may be warranted so as to inform policy analysis on implications of a future proliferation of tokenisation, and support further potential efficiency in traditional financial market activities in a safe manner.

Figure 1. Potential limits to the take-up of tokenisation



Note: Non-exhaustive list possible reasons for the absence of a market for tokenised assets, depending on the jurisdiction.

2.1. Lack of liquidity and absence of an ecosystem

Pilots and experimentation are only expected to transition to live production if these are commercially viable. This issue is multifaceted and relates both to issuer and investor demand for tokenised assets as well as to the investment required to satisfy such demand associated with the required DLT infrastructure.

The lack of liquid markets for tokenised assets impedes large-scale investor participation. Equally, in the absence of a critical mass of investors, issuers may be reluctant to proceed with primary issuance of tokenised instruments. Congregating a critical mass of participants is challenged by the absence of sufficient liquidity and results in such absence of liquidity at the same time. A catalyst potentially could help resolve this liquidity conundrum. One such catalyst, for example, a sovereign bond issuer issuing on DLTs,

could help kick-start an ecosystem at least at a local level (e.g. Republic of Slovenia's inaugural digital bond in 2024 (Republic of Slovenia, 2024[9]).

The existence of key parts of a capital markets "ecosystem"[2] can accelerate such transition, as has been the case in Switzerland (see Box 1). In addition to fundamental operational reasons for a fully functional market, the existence of an ecosystem would also assist with liquidity in primary and secondary markets for tokenised assets, driving increased levels of institutional adoption. In addition, the smooth functioning of such ecosystem requires the coordination and interoperability of numerous moving pieces including in regard to asset and trade lifecycles that must be digitised. For example, the near real-time atomic settlement made possible by tokenised assets would impact current trading practices for the same asset traded off-chain, and time may be needed to adapt, synchronise and ensure the smooth simultaneous trading of on-chain and off-chain instruments for the same reference asset.

Box 1. The experience of Switzerland: Helvetia pilot

Helvetia is a pilot project of the Swiss National Bank that started on 1 December 2023, and represents the world's first issuance of a wholesale CBDC (wCBDC) on a regulated third-party platform to settle commercial transactions with tokenised assets.

Participating banks in the project can use Swiss franc wCBDC to settle transactions with tokenised bonds on SIX Digital Exchange (SDX), a regulated trading and settlement platform for tokenised assets. Since the start of the pilot, seven tokenised bond issuances and one secondary market transaction have been successfully settled in wCBDC. In addition, the SNB carried out the world's first monetary policy operation in a production environment on a distributed ledger, by issuing digital one-week SNB Bills on SDX.

The issuance of wCBDC on a third-party platform entails a public-private partnership: SNB delegates certain tasks related to the issuance and use of central bank money to the platform provider, with clearly defined roles, responsibilities, rights and obligations, and certain contractually agreed tasks to SDX. At the same time, the SNB retains control and monitoring capabilities over the use of its wCBDC. Such capabilities are made possible by operational and technical means on the SDX platform. The rare conditions in Switzerland, that include the existence of a vibrant full DLT-based ecosystem, and the close cooperation of the financial authorities with large financial firms in the country have supported the development of highly novel projects such as the issuance of central bank liabilities on a third-party platform.

In Project Helvetia, participating banks tokenise sight deposits and de-tokenise wCBDC through the Swiss RTGS system in a standardised, automated process. For this to work seamlessly, the operating hours of the Swiss RTGS system and SDX are aligned. If multiple third-party platforms with wCBDC were to exist, this approach could be replicated.

Source: SNB (2024[10]), Project Helvetia III - The SNB's pilot for wholesale CBDC, https://www.snb.ch/en/publications/communication/speeches/2024/ref_20240506_tjn.

The lack of a full ecosystem able to participate in DLT-based finance is also impeding the development of a market for tokenised instruments. One of the reasons for the possible absence of ecosystem could be the tendency to consider a purpose-built DLT infrastructure that could replace the existing traditional infrastructure, instead of focusing on an integration of DLTs with traditional infrastructure. In many cases, the majority of process involved in the tokenised asset lifecycle are performed on chain as well as replicated ('mirrored') traditionally, and as such, none of the possible efficiencies have materialised (e.g. book-building both on- and off-chain). In the absence of traditional market stakeholders participating in

DLT-based finance, investors seeking to participate in such markets may also leverage purpose-built DLT-trading platforms, which could also include non-regulated entities and platforms and not regulated FMIs. Also, in some cases, some market participants act in non-compliance with applicable rules, regulations, and laws. Another issue arises in cases where institutions are replicating on DLTs the same ecosystem of traditional financial markets without providing a clear rational for investment on something that replicates what is already available and functioning properly.

Increasingly, products aiming at reducing back-end friction (e.g. back-office operations, data reconciliations) without requiring a full end-to-end DLT-based cycle are emerging, with custodians being at the centre of their success (see Section 3.5). These aim at taking advantage of possible efficiencies at the reconciliation and post-trade phase without affecting the infrastructure requirements of the end investor and without requiring a full transformation of the infrastructure used by end investors.

2.2. Measurable, materialised benefits; investment costs and lack of scale

Some of the expected benefits of tokenisation may become more evident at scale, rather than in pilot projects. This may also relate to the fact that efficiencies on DLT-based systems can also depend on network effects. In the absence of a clear economic rationale for the transition to DLTs, market participants may be reluctant to pursue such migration or investment in integration with DLTs. Such proven and measurable economic justification would include actual, measurable, materialised efficiencies and cost reductions that may not be fully observable in small-scale pilot projects, and a measurement of the investment required for the transition to an on-chain environment. Ultimately, the decision about developing and scaling the market relies on the industry itself, and market participants may not be comfortable scaling before seeing evidence of benefits. In addition, some of the benefits of tokenisation could be achieved in existing systems today (e.g. fractionalisation through securitisation) so the market demand for these products can also be unclear depending on the case.

The important investment needs in infrastructure that are required to be able to participate in tokenisation transactions are also potential obstacles to its development and could be exacerbated in case outdated legacy systems are involved. Institutions operating with considerable “tech debt” associated with outdated legacy systems and do not have budgets for potentially significant investment required to adopt DLT, although the relative costs of the use of DLT systems may not necessarily translate into a requirement for a high-cost infrastructure and may depend on the institution and the use case. Naturally, such investment decisions would also require that any and all domestic and cross-jurisdictional legal issues outstanding be already addressed (see Section 3.8, e.g., ownership and property rights and legal frameworks for addressing digital forms of property). The lack of maturity of the technology involved and questions around its scalability and interoperability (between DLTs, too), as well as the fragmented technology environment of DLTs further complicate such decision-making by financial market participants.

Earlier OECD analysis highlighted the need for a solid business rationale for the use of DLTs and tokenisation that would justify the cost of implementation of such technologies, and which could be justified by increased realised efficiencies; increases in safety and trust; reduction in complexity and disintermediation; or by the absence of existing trading infrastructure for the asset (OECD, 2020[1]). Wider adoption of tokenisation was therefore expected in markets with limited liquidity and multiple layers of disintermediation, such as private placements of non-listed SME securities. Conversely, the adoption of tokenisation in equity markets of developed economies, which already enjoy high levels of trust and are supported by fast, safe and efficient processes was at the time deemed insufficient to justify the transition to DLT-based systems as there are very little net incremental efficiency gains achievable, as compared to the cost of upgrading the infrastructure and systems of all market participants.

Box 2. Digital Securities Sandbox (DSS) in the United Kingdom

The Digital Securities Sandbox (DSS), launched on 30 September 2024, is the product of collaboration between HM Treasury, the Bank of England, the Financial Conduct Authority, and the financial services sector. The overarching aims of the DSS are to facilitate innovation, protect financial stability and safeguard market integrity.

The DSS is a regulated live environment that has been created to help the sector explore how developing technologies could be used by firms to transform financial market infrastructures (FMI), in particular through utilising distributed ledger technology (DLT). Specifically, it enables firms to build FMIs that can create, trade, settle and administer digital securities and is open to firms of all sizes and at all stages of development as long as they are legally established in the UK.

To do this, the DSS provides a temporarily modified legislative and regulatory framework, which firms participating in the DSS will be subject to. Changes include temporarily modifying key definitions in legislation to ensure they can accommodate new technology, the powers to modify requirements and ultimately the ability to test new commercial structures (in particular consolidating the activity of a Central Securities Depository (CSD) and a trading venue in one entity bringing the trading and settlement of financial instruments into a single FMI).

The DSS provides a staged approach for participants, whereby they proceed through a series of gates, with requirements becoming more stringent as they progress. Firms in the DSS are subject to volume limits set by the Bank of England, and as a firm progresses through each stage of this 'glidepath', the amount of permitted activity that they can do can increase. It is envisaged that this staged structure will encourage firms to eventually permanently operate outside of the DSS, providing a smooth transition from inside to outside.

Activities taking place in the DSS will be 'live'. In other words, this will involve issuing, trading, and settling real securities, which can either be digitally native or tokenised versions of existing assets. The instruments in scope of the DSS are regulated instruments such as corporate bonds, government bonds, equities, money market instruments (such as commercial paper and certificates of deposit), units in collective investment undertakings (fund units), and emissions allowances.

The DSS can also be adapted in case any new barriers in regulation/legislation are identified. HM Treasury has the power to bring other parts of UK legislation into the DSS to be temporarily modified, even if they are not currently in scope. In addition, HM Treasury can make permanent changes to UK legislation, if necessary, before the end of the DSS, after having reported to Parliament. The DSS is due to last five years (though this can be extended).

Finally, the UK government has announced that it intends to use the DSS to launch a pilot digital gilt instrument (DIGIT), using DLT. This pilot will enable the Government to explore the potential benefits that DLT could bring to the debt issuance process, as well as stimulate the wider development of DLT platforms and infrastructures across UK capital markets.

Source: HM Treasury; Bank of England (2024[11]), Digital Securities Sandbox (DSS), https://www.bankofengland.co.uk/financial-stability/digital-securities-sandbox

2.3. The need for payment rails integrated in DLTs and wholesale CBDCs

For the purported benefits of tokenisation to materialise at the post-trade, the payment rails need to be fully integrated with the DLT network and – until recently – the absence of forms of tokenised money could explain in part the absence of development of these markets. The existence of DLT-based payments could allow for the simultaneous and seamless DvP at the post-trade of DLT-based assets transactions, allowing for the payment leg of the settlement process to also be performed in an on-chain environment.

A tokenised form of central bank currency, such as a CBDC, or other forms of tokenised private money (e.g. tokenised deposits) or appropriately designed and compliant stablecoins need to be used for the payment leg of the transaction, for DvP to be effectuated. Alternatively, the traditional wholesale payment rails need to be connected with the distributed ledger, as was successfully achieved in the experiment of Project Helvetia in Switzerland through the connection of the central bank-run real-time gross settlement (RTGS) system with the DLT network (see Box 1) (SNB, BIS Innovation Hub, SIX, 2020[12]).

It should be highlighted that the existence of stablecoins or tokenised deposits is not necessarily sufficient, as these instruments still involve counterparty and liquidity risks. Additionally, private tokenised monies, such as stablecoins, may entail departures in their relative exchange values away from par in violation of the "singleness of money" (Garratt and Shin, 2023[13]). According to the CPMI/IOSCO Principles for Financial Markets Infrastructures (PFMIs) a financial market infrastructure (FMI) should conduct its money settlements in central bank money, where practical and available, and if central bank money is not used, an FMI should use a settlement asset with little or no credit or liquidity risk, such as commercial bank money. As such, an ideal payment instrument for DvP would be wholesale CBDC, still at exploration or pilot phase in most jurisdictions. Tokenised deposits (tokenised commercial bank money) could also be an alternative. In the future, a common interface for CBDCs and tokenised assets could be envisaged by central banks, such as the BIS Unified Ledger (BIS, 2023[14]). Also, the cross-border functioning and interoperability of CBDCs (both at the operational and at the regulatory level) would need to be achieved as a potential prerequisite of global tokenisation markets to be fully functional (e.g. BIS Hub Project Meridian).

Although many wCBDC initiatives have been undertaken, are ongoing or are in the research and development pipeline, it could be years before wCBDCs come to full fruition. The operational successful accomplishment of such initiatives is not sufficient, as legal and regulatory prerequisites will need to be also achieved. For example, central banks must have the authority in the relevant legislation to issue token-based CBDCs. According to some analyses[3], the legal status of account-based CBDC under private and public law is “well developed and understood [but] digital tokens, in contrast, do not benefit from a long history and their legal status under public and private law is currently unclear.” IMF research suggests that 61% of IMF-member country central banks could not issue token-based CBDC, and the laws were unclear in 16% (IMF, 2020[15]).

It should be noted, however, that wCBDC is a broad concept, not necessarily linked to any specific digital technology, as it encompasses all forms of settlement of interbank and related wholesale transactions in central bank reserves. In practice, two main macro-models of wholesale CBDC can be distinguished: (i) the "Bridge" solutions (also known as "Trigger"), which envisage the implementation of a hybrid model, in which the settlement of wholesale transactions in central bank money takes place on infrastructures based on non-DLT technology that are linked to external systems, based on DLT technology, for the settlement of digital assets; (ii) the "Full DLT" solutions, which envisage that both the settlement in central bank money (issued as "native digital assets") and the settlement of digital assets take place on platforms based on DLT technology. This option would thus provide for the creation of a wholesale settlement system based on DLT technology, in which settlement in central bank money would take place in "DLT-based" central bank money. Examples of bridge solutions are the experiments of delivery versus payment in euro via a 'bridge' between DLT platforms and the large-value payment system TARGET2 (see Deutsche

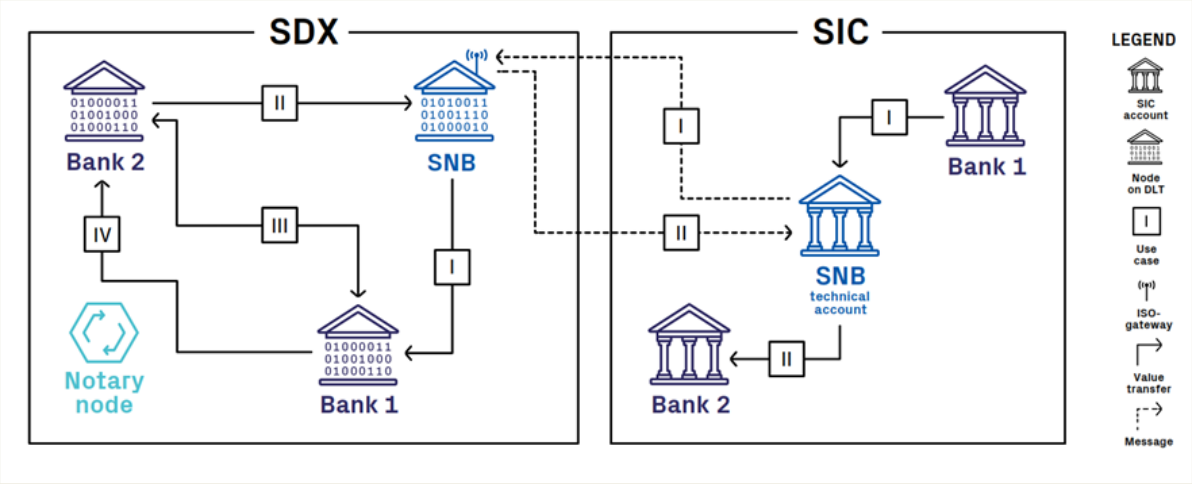
Bundesbank (2021[16]) and Box 4) or Banca d'Italia's TIPS "hash link" solution, which is based on APIs. Compared with the trigger solution by Deutsche Bundesbank, the hash link solution is technologically neutral, being API-based, and is not bespoke, allowing for great ease of use (Banca d'Italia, 2022[17]).

Box 3. Integration of wholesale CBDCs (wCBDCs) with existing infrastructure: initial phases of Project Helvetia

Project Helvetia was a multi-phase investigation by the BIS Innovation Hub, the Swiss National Bank (SNB) and the financial infrastructure operator SIX. It demonstrated that a wCBDC can be integrated with existing core banking systems and processes of commercial and central banks. Furthermore, it showed that issuing a wCBDC on a DLT platform operated and owned by a private sector company is feasible under Swiss law.

Helvetia Phase II tested six use cases related to wCBDC settlement (see Figure 2). A commercial bank (Bank 1) initiates the issuance by transferring funds from its SIC account to an SNB technical account in its Swiss RTGS Swiss Interbank Clearing (SIC) system account. This triggers a message from SIC to the SNB node in the SIX Digital Exchange (SDX). Upon receipt of the message, the SNB node issues the equivalent amount of wCBDC to the Bank 1 node, with the notary node validating the transaction. Once wCBDC exists on the platform, Bank 1 can conduct delivery-versus-payment (DvP) transactions with Bank 2 (use case III) in addition to wCBDC free-of-delivery payments to Bank 2 (use case IV). State changes to the ledger stemming from the transactions are signed and time-stamped by the notary node. The process ends with the redemption of wCBDC which the Bank 2 node triggers by sending a redemption request to the SNB node (use case II).

Figure 2. Illustrative example of settlement process



Note: Intraday control and monitoring of wCBDC settlement by the central bank
Source: SNB. (2024[18]), Project Helvetia I and II, https://www.snb.ch/en/the-snb/mandates-goals/international-cooperations/multilateral/bis-innovation#t30 .

Box 4. Lessons learned from wCBDC pilots used in tokenised assets transactions

Some central banks have piloted or done proofs of concepts (PoCs) of DLT-based securities settlement platforms that use CBDCs in transactions and settle in wCBDC. Such experimentation has generated some insights on the possible benefits of tokenisation, while also pointing to certain limitations or to the impact of such usage for market structure and liquidity. It should be also noted that some of these central banks have subsequently terminated their CBDC projects. In particular:

- The Reserve Bank of Australia found that the digitisation of syndicated loans on a DLT platform could provide efficiency gains and reduce operational risk by replacing highly manual and paper-based processes. Integrating a wholesale CBDC on the same DLT platform enabled "atomic" delivery-versus-payment (DvP) settlement of the drawdown, novation, and repayment of the tokenized syndicated loan, and could potentially allow for other forms of programmability that could improve efficiency and reduce risk in transactions. The pilot was completed in 2023 (Reserve Bank of Australia, 2023[19]).
- The South African Reserve Bank concluded that the number of intermediaries could be reduced and some of the functions performed by existing infrastructures could be collapsed onto a single platform, which could lead to reduced costs and reduced complexity (South African Reserve Bank, 2022[20]).
- The Bank of Thailand found that the outcomes of its study are promising as it was able to streamline and automate existing processes through the use of workflows driven by smart contracts. The pilot concluded in April 2024 (Bank of Thailand, 2024[21]).
- The Bank of Canada concluded that while DLT shows promise in terms of efficiency improvements, a significant expansion of the scope of coverage of the ledger to include additional assets and the full trade and post-trade life cycle may be required to realize these benefits. With this work completed, and with other payments issues gaining prominence, the Bank of Canada decided to scale down its work on a retail CBDC and shifting its focus to broader payments system research and policy development (Bank of Canada, 2024[22]).
- As discussed in the report by the SNB, BIS Innovation Hub and SIX (BISIH, 2024[23]), instant gross settlement requires prefunding of the asset leg and the cash leg, which could alter market structures and require significant amount of liquidity for settlement while potentially fragmenting the supply of liquidity (SNB, BIS and SDX, 2022[24]). Novel liquidity-saving mechanisms or new money markets for immediate and intraday liquidity may be required.
- Deutsche Bundesbank concluded that it was possible to settle tokenised securities primary and secondary market transactions instantly in central bank money with no need for a CBDC (Deutsche Bundesbank, 2021[16]). This and other similar efforts, such as the one by Banca d'Italia (Banca d'Italia, 2022[17]) suggest that having on-chain tokenised CBDC is not necessary for tokenisation markets to function. Instead, DLT-based securities settlement was completed with the aid of a "trigger" solution and a transaction coordinator in TARGET2, the Eurosystem large-value payment system. These and other, similar efforts to create "synchronisation" also suggest that a "single ledger" solution is not necessary for tokenisation markets to function.
- The Banque de France has conducted, since 2020, 14 experiments in PoC and real, testing a wide range of use cases for the settlement of tokenised assets with wCBDC provided by its own DLT (namely DL3S). The two reports published, respectively in 2021 and 2023, highlighted that (1) interoperability between both private and public DLT (or legacy system) should be the priority; (2) financial stability can benefited from the use of a DLT to manage both trading and post-trading operations and (3) DLT could be a useful device for central bankers to control the issuance of central bank money under a tokenised form.

2.4. Atomic and programmable settlement: is T+0 even desirable to every market participant?

One of the major sources of expected post-trade benefits of tokenisation lies in the 'atomic' settlement, i.e. the simultaneous transfer of ownership of the tokenised instrument and the corresponding payment, if and only if both are in place, thus eliminating counterparty risk. 'Atomic' settlement, equivalent to 'simultaneous' settlement, does not need to be also instant (Lee, Martin and Müller, 2022[25]). In fact, while simultaneous settlement is probably always desirable, instant settlement may not be, given possible unintended consequences of instant settlement: it can significantly restrict the set of permissible trades, making netting of settlement obligations impossible and allowing for the execution of only trades in which cash and securities are pre-positioned; and it can fundamentally alter the information environment in which traders operate as traders can only sell securities they already hold, which reveals information about past trades (Lee, Martin and Müller, 2022[25]). The latter can lead to a hold-up problem as intermediaries must purchase assets in advance to facilitate a transaction and even breakdown trade altogether (Lee, Martin and Townsend, 2021[26]).

Increased pre-funding requirements, the absence of netting, and the increases in liquidity needs may render simultaneous and instant delivery versus payment unattractive for some financial market participants. Given programmability functionalities of smart-contract based DLT applications, programmable settlement that is not instant but is simultaneously could be achieved for tokenised assets. Still, questions arise as to the optimal intervals for such settlement, together with their impact on current post-trade processes and the potential implications of atomic settlement for current trading practices.[4] For example, the higher volumes of securities that would need to be moved in gross terms would result in an increase in trading costs as traders would have less time to source the increased liquidity needed for settlement; traders may rely on prime brokers and security lenders to source liquidity; and wCBDC or other payment instrument would need to be pre-positioned for maximum intraday needs to avoid revoked transactions and imposition of settlement failure penalties.

2.5. The key role of custodians for the onboarding of assets – the example of repo transactions

The lack of maturity or limited availability of digital assets-related services by custodians could be another key parameter in the limited development of markets for tokenised assets. The role of custodians in these markets is key as they onboard customers to DLT platforms (investors are unlikely to onboard to DLT platforms directly). The role of such trusted parties is not limited to onboarding and transitioning/connecting the off-chain to the on-chain world, but importantly, involves the safeguarding of the asset where off-chain assets are involved (e.g. Lichtenstein legal framework for non-native tokenisation)[5].

For example, custodians can help investors enjoy the potential benefits of DLT-based systems for repo transactions. It should be noted that programmable repo and tokenised collateral management transactions are prime use cases of post-trade DLT-based finance, that do not necessarily require the primary issuance of the security to be done on-chain by the issuer. For that to be achievable, custodians would need to have the necessary infrastructure to tokenise collateral and participate in DLT-based repo platforms, reaping any purported benefits of back-end friction reduction, costs savings and settlement fail reduction.

The second dimension to the key role of custody in the context of tokenised assets relates to the need for a trusted and credible central party that will guarantee the backing of tokens issued with 'real world' off chain assets as the reference assets, as well as hold such assets in custody, in addition to custody of natively digital tokenised assets. The former involves the custody of underlying assets held in reserve to

collateralise tokenised asset issuance and to ensure that assets such as real estate are being tokenised only once (OECD, 2020[1]). In essence, such custodians guarantee the connection of the off-chain world to the distributed ledger environment, ensure that the digital representation of the asset on the ledger is unique and that the same asset is not being represented by multiple tokens in multiple platforms.[6] Regulatory requirements in many OECD jurisdictions prescribe that reserve assets should be stored with properly regulated, capitalised, and operated financial institutions ('qualified custodians').

In the scenario where the tokenised asset issuer is a qualified custodian with the legal and regulatory authority to custody funds on behalf of customers in the context of the respective tokenised asset issuance, they may themselves be the qualified custodian with which reserve assets are held. However, in the scenario where the tokenised asset issuer is not a qualified custodian with the legal and regulatory authority to custody funds on behalf of customers in the context of the respective tokenised asset issuance, the issuer may be expected to structure an arrangement with such a qualified custodian to custody reserve assets. Regulated qualified custodians are important also in light of potential unregulated entities that may wish to take over such roles of custody; as well as given the self-custodial nature of some un-hosted wallet applications existing in decentralised finance markets and that may technically be able to hold tokenised assets (self-custody of private keys).

Anecdotal evidence by market participants suggests that while traditional custodian firms have increasingly started to offer digital assets custody services, the uptake has been reported by the market to be initially concentrated on the provision of services related to mainstream crypto-asset holdings by investors (e.g. Bitcoin, Ether) rather than to onboarding of investors to DLT-based tokenised instruments. This may be driven *inter alia* by the fact that some institutional investors are already holding crypto-assets in their portfolio and are showing interest in investing in tokenised products in the future as these gradually emerge.

2.6. Choice of DLT network architecture and complexity of interoperability challenges

Most financial service provider initiatives so far have leveraged private permissioned DLTs, not least given the importance of addressing the AML/CFT and illicit finance concerns associated with public permissionless ledgers (e.g. Ethereum). However, the use of private permissioned networks may restrict participation to the network to the firm's clients and may end up rather centralised and fragmented.

With pockets of activity scattered around the system, interoperability becomes an even more complex issue and the full purported benefits of being part of a network cannot necessarily materialise. Links built between these pockets of activity using standards for DLT interoperability[7] could result in the pooling of liquidity while still allowing for controls on the assets and their owners/transacting parties. This requires the development of technological interoperability between a variety of different, but connected, ledgers, via interoperability solutions, to form liquidity across markets. It could also include the potential integration between the DLT-based and legacy infrastructure. Potential operational and technological risks arise from the use of linkages, depending on their type (e.g. increased cyber-risk if bridges are used to connect tokenisation platforms). That said, current payment systems and all other financial system are also not interoperable.

Some pilot projects are built on public permissioned DLTs with centralised control as to the participants to the network, with validation of who can have access to the system (e.g. through whitelisting or other emerging tools to enable KYC/AML/CFT compliance) and permissioning on what assets can be transacted. The use of public networks for the validation could allow for the settlement efficiencies to materialise, although there may still be limitations related to scaling and interoperability. That usually requires an additional layer to address such issues, and that is often a centralised solution.

Permissionless ledgers are considered by the industry as allowing for scaling, greater interoperability and resilience. However, it is difficult to conceive any scenario of financial services being provided on permissionless DLTs without any type of onboarding or identification of transacting parties or control over the asset (e.g. ability to freeze/immobilise/clawbacks) unless such controls are already incorporated into the smart contract code. In addition, there are issues with uncertainty regarding whether the transaction will be processed, and in relation the probabilistic settlement finality in some consensus mechanisms.

Potential hybrid structures with permissioned products with token issuer controls built on top of permissionless ledgers, the latter used only for validation, could allow for greater interoperability at the settlement layer. A number of issuers are presently using public, permissionless blockchains to tokenise their securities and are able to create permissioning (or "whitelisting") at the application layer by, for example, coding the smart contracts that govern the issuance and transfer of the tokens in such a way that controls exist. However, that does not resolve fragmentation that could result from a lack of interoperability between existing and legacy infrastructure, and the cost and coordination challenges associated with that; or mitigate risks related to the use of permissionless networks for financial transactions (BIS, 2024[27]).

2.7. Lack of identification solutions and absence of global (industry) standards

The use of identification solutions can reduce the burden of technical due diligence for all stakeholders participating in the same ecosystem and allows for the easier accreditation as in the case of whitelisting solutions for participation in public networks. Solutions and standards for the identification of investors can allow for automatic whitelisting of investors allowing them to invest only if they fulfil certain suitability criteria in line with the ones set by the regulator, depending on the jurisdiction. Securities asset servicing and corporate actions such as dividend distribution or lock-up periods are programmed in the standard and apply automatically without any further intervention.

Solutions for the identification of tokens (such as the Digital Token Identifier (DTI) ISO standard[8]) can assign unique identifiers to digital ledgers and tokens, providing a consistent standardised manner of identifying tokenised assets across networks and jurisdictions. This can potentially support the integration of tokenised assets with the traditional financial system, while also supporting the possibility of a single instrument being tokenised on multiple blockchains and avoiding that a token is referenced twice.

Data and messaging norms and standards have historically supported the development of financial markets[9] but remain underdeveloped when it comes to tokenised assets. This could include identifier standards, technical standards or interoperability standards, that could support global connectivity and interoperability.

Similarly, the lack of clear domestic accounting standards in many jurisdictions for the treatment of tokenised assets throughout their lifecycle do not support further uptake of these instruments and could also pose challenges for their integration with traditional financial systems. For example, when underlying assets are moved into custody to back a tokenised asset issuance, how should those assets be classified on the issuer and custodian’s balance sheets: as assets or liabilities? Further, if a tokenised asset issuance in one digital environment is used to back a tokenised asset issuance in another digital environment, how should those two sets of tokenised assets and the underlying assets now be classified on balance sheets for all involved? The initial issuance and potential daisy chaining of additional tokenised asset issuances may create a dubious accounting standards dilemma with regards to mitigating the risk of artificial asset-side balance sheet ballooning.

2.8. Legal issues

Depending on the jurisdiction, several legal questions around tokenisation remain to be addressed before this technology can realise its purported potential to improve financial services at scale (OECD, 2021[2]). Such limitations include, for example, the fact that ownership of a token does not necessarily accord ownership to the underlying asset; the legal status of smart contracts; limits with regards to settlement finality when using DLTs, to name a few (OECD, 2021[2]). Similar questions arise also across jurisdictions and across borders, where differing legal treatments may accentuate potential issues and/or discrepancies.

Indicatively, in some cases, a change in ownership for a tokenised security on the ledger may not be considered a legally recognised change in ownership unless a regulated intermediary registers the change in ownership in the off-chain environment. This creates a slew of challenges with respect to the corresponding legal, operational, and coordination considerations and complicates instead of alleviating the back-office processes required to transact. Also, uncertainty in some jurisdictions around whether digital assets are recognised as property under private law renders it difficult to determine with certainty the legal claim investors can have over tokenised assets, how tokens can be subject to enforcement, what their position is in a bankruptcy proceeding, or whether the holder of an asset will get access to the tokenised instrument in case of custodian default.

3 Applying technology neutrality to tokenisation

Given the technology-neutral approach to financial regulation that most OECD member economies follow, the deployment of DLT and tokenisation in financial markets should comply with existing regulatory requirements that promote financial stability, financial consumer and investor protection, and market integrity, while promoting competition in these markets. The introduction of DLTs and tokenisation should be seen as merely replacing one digital technology (electronic book-entries in securities registries of central securities depositories) with another (cryptography-enabled dematerialised securities based on DLT-enabled networks) ceteris paribus, therefore raising no issues in these jurisdictions with a technology-neutral approach to regulation. This may not be the case when there is a change is the composition, function and number of players involved; and when technology brings new issues - such as settlement finality.

In terms of regulatory environment, participants in tokenised assets transactions should comply with appropriate regulatory and supervisory requirements in place (OECD, 2021[2]). The principle of technology neutrality (same activity, same risk, same regulation) employed by financial regulators in OECD countries does not discourage or promote any type of technology. Financial market participants are therefore expected to demonstrate risk management and control process commensurate with whichever technology or platform they deploy as part of their activity.

Despite the applicability of existing laws and the potential usefulness of traditional regulatory tools, however, there may be a need to further identify risks that are more acute in DLT-based finance and tokenisation that may warrant additional policy considerations. Examples of risks inherent to DLT-based finance can include technology and cybersecurity risks and vulnerabilities; pseudonymity[10] and anonymity enabled through the use of DLT; AML/CFT and investor and market protection risks; lack of visibility into actual control; and conflicts of interest and collusion; cyber-risk; vulnerabilities of a blockchain, such that a disruption or failure that underpins a particular product or service; smart contract risk, which adds additional risk to the underlying IT operational risks, such as code errors, private key compromises and re-entrancy attacks, among others. Even when there is a relevant regulatory tool to address similar risks, the differences in entity/activity mapping between DLT-based and traditional finance may lead to difficulties in triggering regulation depending on the legal framework in certain jurisdictions. While existing regulatory tools can address the risks, there may exist challenges in enforcing them in some jurisdictions—for example, if regulations are very prescriptive, such that a DLT-based/tokenised transaction would for some reason not be captured.

In addition, gathering data on DLT-based activities is challenging, due, in part, to the opacity of off-chain activities, the poor interpretability of on-chain data, and the pseudonymous nature of counterparties in some contexts. Moreover, certain activities can occur cross-chain, which also significantly hinders the ability of regulators to monitor these activities effectively. Such information gaps could make it difficult for regulators to conduct market surveillance, monitor the evolution of risks or assess growing interlinkages.

The transformation of capital markets requires the coordination and interoperability of numerous moving pieces in asset and trade lifecycles that must be digitized. For example, the near real-time settlement made

possible by on-chain tokenized assets, brings many potential benefits to market participants, but it could have a major impact on current trading practices as well in the future.

Whether or not an institution adopts DLT technology is a business decision on their part. Policy makers should continue to track developments in this area, while financial supervisors in particular may have a role in understanding DLT technology well enough to be able to supervise activities leveraging this technology and conclude on whether risk management practices are sufficient to identify, measure, monitor and control risk.

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Notes

[1] Referring to Model 1 DvP as defined by CPMI whereby systems that settle transfer instructions for both securities and funds on a trade-by-trade (gross) basis, with final (unconditional) transfer of securities from the seller to the buyer (delivery) occurring at the same time as final transfer of funds from the buyer to the seller (payment) (BIS, 1992[28]).

[2] A plethora of financial markets participants would form such ecosystems including market activity facilitators, legal and regulatory process facilitators, asset custodians, market activity administrators, trading firms, as well as regulators, legislators, and any sub-categories of financial market participants servicing niche and nuanced use cases throughout asset and trade lifecycles.

[3] Analysis is based on two types of CBDC from a central bank law perspective (not to be confused with economists' classification): "Account-based" that merely digitises balances in cash current accounts in the central bank books, and "Token-based" taking the form of digital token not connected to an account relationship between central bank-holder.

[4] For example, the International Securities Services Association suggests that, because records are centralised on the same underlying ledger, there could be a tokenised asset central counterparty (CCP) running batches which are not atomically settled (ISSA, 2021[29]).

[5] This is less applicable to the Luxembourg legal framework of tokenisation, where the rights adhere in the token, so that custodian role is arguably diminished.

[6] E.g. in Liechtenstein where regulations around validating underlying asset reserves for tokenised assets has created a new type of intermediary for reserve asset verifying service providers (OECD, 2021[2]).

[7] E.g. Chainlink's Cross-Chain Interoperability Protocol (CCIP) (Swift, 2023[30]).

[8] The sequence of nine alphanumeric characters representing a DTI cannot be changed or modified once assigned.

[9] e.g. SWIFT; ISO standards for currency codes (ISO 4217), securities data definitions (ISO 7775/15022/20022) payment data definitions (ISO 20222).

[10] i.e. the use of a different name from the user's real name.