Tokenization and Financial Market Inefficiencies

Itai Agur, Germán Villegas-Bauer, Tommaso Mancini-Griffoli,
Maria Soledad Martinez Peria, and Brandon Tan

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I. Introduction

Recent advances in digital technologies are transforming financial markets. Improvements in computer hardware, networking infrastructure, and software development have facilitated new financial activities such as high-frequency trading (Brogaard, Hendershott, and Riordan 2014; Jacob Leal and others 2016), mobile banking and payments (Shaikh and Karjaluoto 2015; Tam and Oliveira 2017), and crypto-asset issuance and trading (IMF 2023).

Tokenization is considered one of the recent financial innovations facilitated by technological changes (Aldasoro and others 2023; FSB 2023; Banerjee and others 2023). Several government-sponsored initiatives, involving central banks and private financial institutions, have been recently announced or are underway to test its potential effects.[1] The Boston Consulting Group estimates that, by 2030, asset tokenization could reach $16 trillion or 10 percent of global GDP.

This note examines the potential impact of tokenization on financial markets. In particular, it presents a conceptual framework rooted in economic first principles to consider the effect of tokenization on market inefficiencies. Inefficiencies are grouped into two broad categories (Figure 1). The first is frictions, which include information asymmetries, search problems, transaction costs, and counterparty risks. The effects of frictions on financial markets can be usefully analyzed along the lifecycle of an asset (issuance, exchange, servicing, and redemption), as shown in Figure 1. The second category includes externalities, internalities, and market power.[2] This note takes existing market structures (including the role of intermediaries) and regulation as given. To the extent that tokenization reduces market inefficiencies, policymakers may wish to carefully evaluate their approach to regulating, adopting, and encouraging tokenization developments. This note, however, does not investigate policy responses.

Throughout this note, a digital token refers to an asset or a representation of an asset on a digital ledger that is shared, trusted, and programmable. Sharedness refers to the capacity of transacting parties to possess, acquire, and transfer assets on the ledger. Trust depends on the accuracy of asset ownership and the predictability of transaction orders. Trust is needed for agents to willingly transact on the ledger. Programmability means that assets—the financial applications associated with them, such as repos and swaps—and the conditions for transactions, including the investors permitted to hold certain assets, can all be hard coded into, and executed by, the ledger. Moreover, transactions can be contingent on one another and bundled to occur as one.

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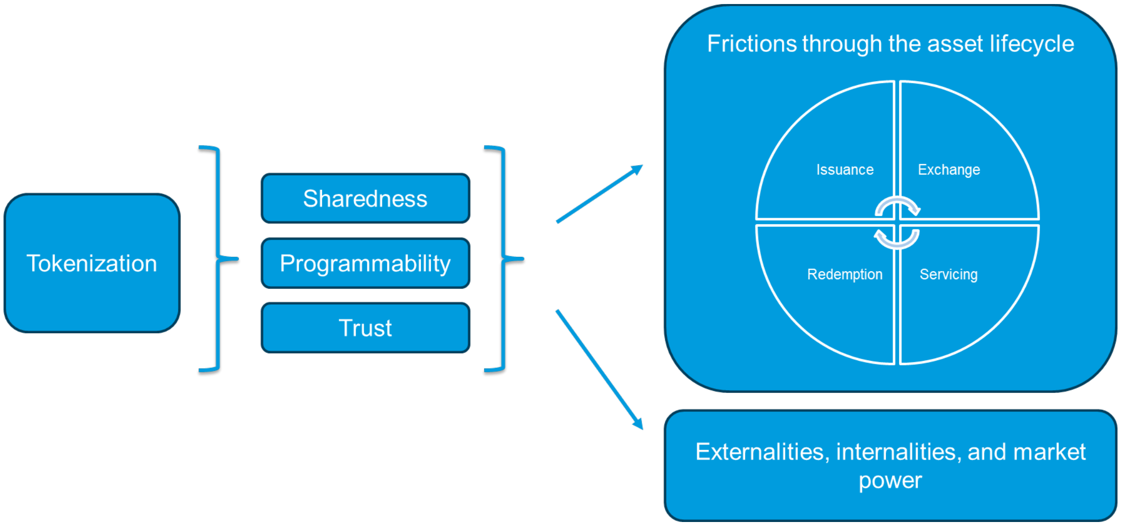
[1] On April 3, 2024, the Bank for International Settlements, together with seven central banks (Bank of France, Bank of Japan, Bank of Korea, Bank of Mexico, Swiss National Bank, Bank of England, and the Federal Reserve Bank of New York), announced plans to join forces with a large group of private financial firms convened by the Institute of International Finance to explore how tokenized commercial bank deposits can be integrated with tokenized wholesale central bank money in a public–private programmable core financial platform (Project Agorá). Project Global Layer 1 and Drex are initiatives involving, respectively, the Monetary Authority of Singapore and the Central Bank of Brazil, aiming to facilitate the issuance, redemption, and transfer of tokenized financial assets.

[2] The effects of tokenization on this set of inefficiencies have repercussions along multiple stages of the lifecycle which are interrelated. For this reason, it is more appropriate to discuss their effects throughout the entire lifecycle in subsections specific to each inefficiency.

The features of token ledgers can be achieved to varying degrees. The features are continuous rather than dichotomic. One ledger may exhibit greater sharedness than another or may support a broader set of programs.

Tokenization refers to the creation of assets or representations of assets on a digital token ledger. The definition of token ledgers used in this note is akin to that considered in studies by Aldasoro and others (2023) at the Bank for International Settlements, the Committee on Payments and Market Infrastructures (CPMI 2024), and the Financial Stability Board (FSB 2024). Similar to these studies, this note discusses distributed ledger technology (DLT) as one (prominent) technological implementation for tokenization, but not as part of what defines a token. This stands in contrast to various other studies, including in the private sector, which tie distributed ledgers to the definition of digital tokens (Banerjee and others 2023; Carapella and others 2023, Hedera). This note's focus on the features of tokenization, which can be implemented in different models (Box 1), guides the choice for a technology-neutral definition. Although the note describes different models of tokenization, the analysis of the effects on market inefficiencies is not specific to a particular model, unless stated explicitly. This note centers on a conceptual analysis, although it also summarizes the few existing empirical estimates of the effects (Box 2).

Figure 1. Overview of Conceptual Framework on Tokenization and Market Inefficiencies



The effects of tokenization on financial market inefficiencies emanate primarily from improvements in the sharedness and programmability features of ledgers, whereas trust is a necessary condition for their utilization. More shared and programmable ledgers have the potential to reduce market frictions in asset issuance, trading, servicing, and redemption. For example, such ledgers could mitigate certain forms of counterparty risk through simultaneous settlement, enable faster settlement, and reduce search frictions. More shared and programmable ledgers may also affect the degree and costs associated with externalities, internalities, and market power. In particular, they may facilitate the spread of shocks across financial institutions, increase the cost of operational risk events, improve liquidity, facilitate positive knowledge externalities, exacerbate retail investor internalities, and affect market power. While tokenization may, in some instances, lessen the need for certain intermediaries, it is more likely to reduce the costs of the processes performed by intermediaries rather than rendering them obsolete. How much of these cost savings will be passed on to investors will depend on the degree of market competition. Regulations have an important role to play in mitigating the potential negative effects of tokenization and may need to be adapted to achieve such a purpose. A discussion of the appropriate regulatory frameworks is beyond the scope of this note and considered the remit of standard-setting and regulatory bodies.

Increases in sharedness are not unique to tokenization and thus some of the implications for financial markets analyzed in this note may apply to changes to other (nonprogrammable) ledgers as well. Unifying disparate ledgers increases sharedness, as more agents come to share the same trading venue. However, such unification is not predicated on tokenization: that is, the resulting unified ledger need not be programmable. This underlines the importance of considering tokenization not as a singular innovation but rather as a package composed of distinct dimensions, some of which can be attained by other means as well. Arguably, the presence of some inefficiencies in financial markets originates from the failure to upgrade legacy systems or market structures, because of, for example, coordination problems, vested interests, or political economy constraints. To the extent that tokenization attains what could have been attained through other means (namely, increases in sharedness), its purpose in current policy initiatives could be a coordination device (to push through reforms) more than a genuine technological innovation. Regarding advances in programmability, however, the “package of tokenization” contains more novelty.

The rest of the note is organized as follows. Section II discusses the note’s definition of tokenization, the fundamental features of digital token ledgers, and the different models that can achieve these features. Section III examines the inefficiencies that are common in financial markets and the role that intermediaries play in addressing some of them. The impact of tokenization on financial markets is discussed in sections IV and V. Section IV considers the potential effects of tokenization on frictions along the lifecycle of financial assets. Section V investigates how tokenization may affect externalities, internalities, and market power. Section VI concludes. Overall, this note takes a positive rather than a normative perspective on the impact of tokenization on financial markets and does not plead for or against its adoption.

II. What Is Tokenization?

A digital token is an asset or a representation of an asset on a digital ledger that is shared, trusted, and programmable.

To transfer tokens on a ledger, the ledger must be shared, which means that transacting parties can own assets recorded on the ledger and instruct the ledger to update ownership. That is, asset ownership rights are embedded and transferable. For the purposes of this note, separate but interoperable ledgers, discussed in Box 1, are equivalent to a ledger to which all transacting parties have access.

To be willing to use the ledger, transacting parties need to trust it for ownership and order purposes. Trust in ownership stems from a token not being transferrable without its owner’s consent and, once transferred with such consent, the recipients’ credence to that ownership is lasting and cannot be suddenly reversed.[3,4] Trust in orders means that instructions on the ledger will be predictably executed, and that confirmation will be accurate and truthful, as well as final.

Programmability means that the ledger stores code-based instructions (smart contracts) that can be used to create an asset or financial application (also called a protocol). For instance, a smart contract can be used to create a transferable bond that pays coupons, or it can be used to escrow and exchange assets. Importantly, smart contracts can include immutable logic that can be automatically enforced every time an asset is transferred. Logic can be used to strictly enforce certain rules, such as to comply with regulations (for example, only allowing qualified investors to transact riskier assets). Furthermore, applications can be combined and reused (referred to as composability). Within the ledger's data and execution environment, applications must be internally consistent. For instance, an asset that is held as collateral in one operation cannot be reused in another unless release conditions are fulfilled. Moreover, multiple steps to a transaction, such as receiving one payment before initiating another, can be executed in a single inseparable transaction (known as atomicity).

An example of a digital token currently in use is Ether, deployed on Ethereum, a network that includes a distributed ledger that is shared and trusted by its users and is programmable. The ledger also contains assets other than Ether and can be programmed to ensure simultaneous exchanges. Ethereum also offers "composability," so that, for example, an interest rate swap and a foreign exchange forward contract can be executed at once.

Different models are possible to attain sharedness, programmability, and trust on a ledger. These are discussed in Box 1. Annex 1 discusses the relation between the models to attain trust and the conditions under which trust can fail.

The creation of assets or representations of assets on a digital ledger that is shared, programmable, and trusted is called tokenization. Tokenization can take place in different forms (Lavayssière 2023). Digital tokens can be created through the issuance of new tokens directly on a shared, programmable, and trusted ledger. This note calls such tokens "native" because they exist solely on the ledger. Digital tokens can also be created as virtual representations of existing assets, such as financial assets held by a custodian. This note refers to such tokens as "non-native," since they are representations of assets that exist outside the ledger.[5] "Migration" refers to the case where a non-native token and the off-ledger asset that it represents are replaced by a native token on the ledger (Lavayssière 2023). A non-native token could potentially represent an asset which is a native token on another ledger. Therefore, digital tokens can migrate from one ledger to another. Figure 2 summarizes our definition of tokenization and the forms by which that creation can be attained.

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[3] The reversal of illicit and fraudulent transactions can constitute an exception to this: a ledger that is overseen by an authority with a capacity to reverse illicit/fraudulent transactions (and with a credible ability to identify cases of fraud, money laundering and other financial crimes, and only reverse transactions in such cases) may be trusted to a larger degree by bona fide users than a ledger where owners have the sole authority over their assets. Currently, trading platforms possess quasi-regulatory powers to oversee trading activity, as they maintain detailed rulebooks for trading, market abuse monitoring, and risk management systems. These platforms are typically overseen by a regulator themselves.

[4] For tokens that are representations of assets outside the ledger, ownership trust also depends on credence in the parity between the off-ledger asset and its on-ledger representation.

[5] There is no consensus in the literature on the definition of a native token. Annex 2 provides a more in-depth discussion on the distinctions that this note makes between native and non-native tokens.

The features that characterize the ledgers where digital tokens are created are not dichotomic variables: sharedness, programmability, and trust can be attained to different degrees. A ledger is considered shared once it has more than one user. Its degree of sharedness increases as more users join, either through onboarding or through merging or attaining interoperability with previously separate ledgers. Similarly, ledgers may support a broader or narrower set of programs. Trust can also be attained to different degrees and a ledger that engenders more trust is likely to attract a larger number of users.[6] As the three features are part of a spectrum, there can be incentives to migrate digital tokens from one ledger to another that enables more sharedness, programmability, and/or trust.

Figure 2. What Is Tokenization?

Tokenization	**Token creation**
Creation of assets or representations of assets on a digital ledger that is:	**Can be attained through:**
▪ Shared ▪ Programmable ▪ Trusted	▪ New issuance (native) ▪ New virtual representation of an existing asset (non-native) ▪ Destruction of an existing asset and reissuance on a ledger (migration)

Box 1. Models to Attain Sharedness, Programmability, and Trust

There are three main models to obtain sharedness: (1) a single ledger, (2) a common ledger, and (3) compatible ledgers. Model (1) entails issuing (native) assets on a ledger on which all (potential) transacting parties (or their intermediaries) have accounts. Model (2) entails creating representations of assets (initially existing on separate ledgers, that is, non-native assets) on a ledger accessible to all parties. This may be accomplished by placing the assets in escrow and requesting the common ledger operator (or third party) to issue escrow certificates that can be owned and transferred among the ledger's participants. Model (3) involves standardizing technology across ledgers so they can run the same programs (smart contracts) and thus offer coordinated transfers (that is, making ledgers interoperable). See Mancini-Griffoli and others (2024) for further details on these models, which the paper associates with platforms.

Programmability on token ledgers differs from more traditional forms of programmability. The distinction relies on where the code used to edit the database is executed. Traditionally, users external to the database pass instructions to the database operator, asking for certain transactions to be undertaken. Instead, tokenization entails internal programmability in the sense that both the code and the database are integrated. Merging the code with the database (the ledger that records transactions) facilitates a greater degree of programmability because it guarantees coherence between them, increasing the efficiency of piecing together transactions into smart contracts that are bundled or contingent on other transactions (Lavayssière 2023).

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[6] This highlights how the features are interrelated, as higher levels of trust would lead to increased sharedness. Moreover, for a ledger to gain any usage, it must attain a sufficient degree of trust (which could be lost if and when that trust proves misplaced).

Box 1 (*continued*)

The models to achieve trust can be classified into three categories: single-operator systems, permissionless DLT, and permissioned DLT. These models achieve consensus on the state of the ledger—ownership of assets—and its programming functions through different mechanisms.[1] Single-operator systems are centralized in the sense that a single entity is responsible to keep records of ownership, execute transactions, and confirm them. Trust in these systems stems from a mix of credibility of the ledger operators, supervision, and legal recourse in case of any wrongdoing. Permissionless DLT relies on a decentralized network of nodes to verify and validate transactions. Information on the state and programming of the ledger is shared across the network and therefore no single operator can unilaterally alter the state or programming functions of the ledger. Whether such decentralization of governance allows users to build trust at a lower cost remains a topic of debate.[2] Validator nodes are incentivized to propose valid transactions through rewards based on newly minted coins and transaction fees. Bitcoin and Ethereum are examples of ledgers based on permissionless DLT. Permissioned DLT is a hybrid between single-operator and permissionless DLT systems, wherein the ledger's validators are onboarded by a central authority.[3]

[1] In DLT systems, such a mechanism is known as a "consensus mechanism," which is an algorithm by which various parties reach an agreement. A consensus mechanism allows nodes (which are the validators in a DLT system) to agree on the status of the network and maintain consistent copies of a single data set. This underlies the ability of a DLT system with multiple nodes to settle transactions.

[2] For example, Budish (forthcoming) estimates that for systems that operate at scale, centralization in a single operator reduces the costs of creating trust. This relates to the so-called Blockchain Trilemma, coined by Ethereum co-founder Vitalik Buterin, wherein the scalability of a DLT system trades off with its degree of decentralization and/or its secureness. However, if there are concerns about the credibility of the central authority, decentralization could potentially enhance trust.

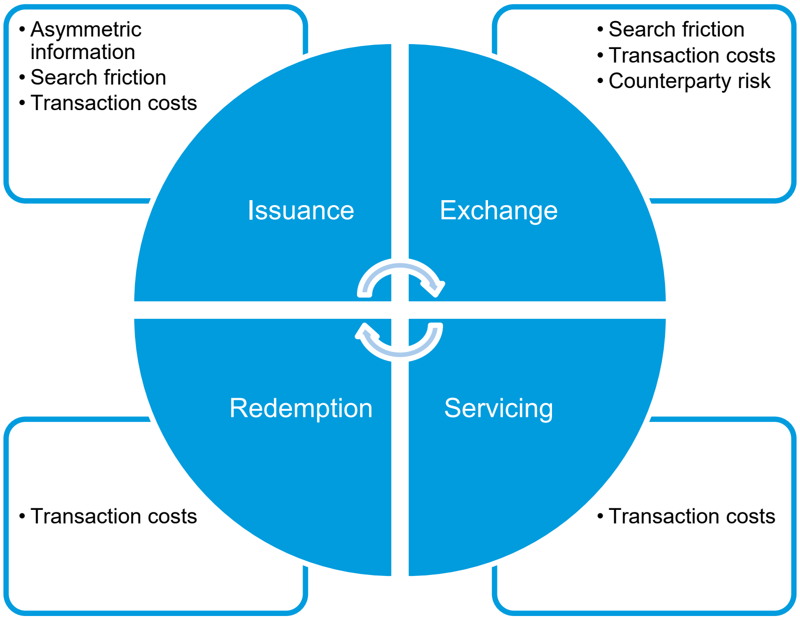
[3] The models to achieve trust and programmability are interrelated. Databases that rely on external programmability are not well suited for ledgers based on DLT systems because, in the presence of multiple operators, determining which operator should execute the external code and update the database information becomes a complex issue. By contrast, with databases that enable internal programmability, instructions are sent as smart contracts that run directly on the ledger (Lavayssière and Zhang 2024). They are pre-validated by all the nodes on the network and provide an automatic confirmation that is generated once the ledger is updated. These databases are well suited to both single-operator and DLT systems.

III. Inefficiencies in Financial Asset Markets and the Role of Intermediaries

This section provides an overview of the types of inefficiencies common in financial markets and the role that financial intermediaries play in addressing some of these. The aim of this section is to set the stage for subsequent sections' examination of how tokenization may affect these inefficiencies in comparison to currently prevailing market structures.

The lifecycle of a financial asset that is traded on a market can be categorized by the processes involved in its issuance, exchange, servicing, and redemption. Issuance is the process of creating and selling new financial assets, such as stocks and bonds, to investors. The issuer may sell these assets to investors through various mechanisms such as initial public offerings (IPOs) or private placements. Exchange refers to the buying and selling of financial assets on the market. Servicing refers to the payment of interest or dividend on financial assets. Redemption is the process of returning these assets to the issuer in exchange for cash or other assets.[7]

Figure 3. Frictions along the Lifecycle of an Asset



Note: This figure does not aim to be fully comprehensive of all possible market frictions present in the lifecycle of financial assets.

The issuance, exchange, servicing, and redemption of assets on financial markets are subject to market frictions (Figure 3). Market frictions are a subcategory of market inefficiencies and include information asymmetries, search problems, transaction costs, and counterparty risks.[8] Asymmetric information is present when one party to a transaction has more information relevant to the transaction than the other. For instance, an entrepreneur taking a company public through an IPO knows more about the prospects of the company than potential buyers know of its assets. Search frictions are impediments to a match, or agreement, between two parties to a transaction, which may result in unrealized trades. For example, an asset issuer might not know which investors may be interested in purchasing its financial assets and how to reach them. Transaction costs include costs of trade and the opportunity cost of the time involved in financial market activity.[9] Counterparty risk refers to the possibility that one of the parties to a contracted trade does not deliver its part. Digital transactions typically involve a single immediate trade, such as buying a stock on a digital platform. For these transactions, counterparty risk results from the potential delay between one party's payment and the other's delivery of a financial asset (or vice versa), which could allow the second mover to cancel its leg of the exchange after the other leg has settled. Derivative

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[7] Not all financial assets undergo the four stages of the lifecycle. For instance, shares of common stock in a company or perpetuities do not have a maturity or redemption date. Another example is bonds that an investor buys on the primary market and holds until maturity: such a financial asset never goes through the (secondary market) asset exchange stage.

[8] The first fundamental welfare theorem of economics states that, under certain conditions, a competitive equilibrium leads to a Pareto efficient allocation of resources (Arrow and Hahn 1971). However, economic activity is often fraught with aspects that violate the assumptions of a competitive market. These are known as market inefficiencies.

[9] Transaction costs can be related to other inefficiencies (like asymmetric information) or could result from intermediary market power.

transactions involve more than just a single immediate trade. For example, a call option includes the initial trade of the derivative for the payment, along with the option for the asset holder to purchase the underlying asset at a specified price in the future. For derivative assets, there is an additional layer of counterparty risk stemming from the possibility that one party to the contract may fail to meet its obligations between the writing of the contract and the time that future transactions are supposed to occur. The nature of both subcategories of counterparty risk is similar, as both emanate from the possibility that the counterparty does not honor its part of the transaction.

Specialized intermediaries reduce market frictions in financial markets at different stages of the asset lifecycle. For instance, investment banks conduct due diligence to assess the creditworthiness and financial health of a company engaging in its first stock or bond issuance. By underwriting the issuance, and thereby putting their established reputations on the line, investment banks act as a “credibility bridge” between a new issuer and investors, mitigating frictions related to asymmetric information.[10] Another example is central securities depositories (CSDs) and centralized clearinghouses (CCHs), which help address counterparty risk. CCHs perform the clearing process, which includes ensuring that both parties have sufficient funds to meet their obligations. CSDs centrally record assets and manage settlement functions, only delivering the assets to the buyer once the payment is made. Such actions address counterparty risks involving immediate trades. Central counterparties (CCPs), a subcategory of CCHs, also mitigate the counterparty risk stemming from the possibility that one party to a derivatives contract may fail to meet its obligations between the writing of the contract and the time that future transactions are supposed to occur. CCPs take on this risk by becoming the counterparty to all transacting parties of a transaction. If one of the parties fails to meet its obligations, the CCP pays the affected party using the margin and any collateral collected from the defaulting party, and if these prove insufficient, it uses its guarantee fund.[11]

Financial markets are also affected by externalities, internalities, and market power. Externalities arise when an agent does not consider how its actions affect other financial market participants or agents in the economy more broadly**.** Externalities can be positive or negative, and both types of externalities can lead a market to socially inefficient outcomes. An example of a positive externality is network effects. For instance, every agent that joins a financial market helps to deepen that market, which can lead to improved outcomes for all participants, such as higher liquidity. However, the joining agent only considers its own costs and benefits from joining, not the benefits to other market participants, and therefore the number of agents in the market may be lower than socially optimal. An example of a negative externality is the socialization of losses for certain intermediaries, particularly those that are systemically important. An intermediary that has implicit or explicit guarantees of a government bailout can have incentives for excessive risk-taking because it internalizes the full upside of risk (that is, higher profits) but not the full downside, some of which is borne by the public safety net. Internalities arise when financial market participants are not well informed or not perfectly rational. This raises the potential for an agent to take an action that is not in its own interest. An example is a retail investor who does not fully grasp the risk associated with a financial asset. Market power refers to the ability of a firm to influence the price of an

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[10] Intermediaries also play key roles in providing risk management, supplying depth to markets by deploying their balance sheets, and ensuring regulatory compliance throughout the issuance process.

[11] Guarantee funds are collected by CCHs from clearing members to cover losses that may arise in the case that a member defaults.

instrument or the terms of a transaction. For instance, if there exist barriers for users to move their funds or other assets across financial institutions, this will provide such institutions with an increased ability to charge higher-than-competitive fees.

The remaining sections of this note discuss how tokenization may affect financial market inefficiencies relative to the status quo. The next section analyzes how tokenization could influence financial market frictions throughout the lifecycle of an asset. Tokenization may be able to reduce some market frictions to a greater extent than intermediaries can currently achieve. Alternatively, it may be cheaper to address market frictions in a tokenized setting.[12] The subsequent section examines how the features of tokenization may affect externalities, internalities, and inefficiencies from market power. The effects of tokenization discussed in this note emanate from changes in the features that define tokenization, that is, the degree of sharedness, programmability, and trust of digital token ledgers. Changes in these features may take place under any of the tokenization models discussed in Box 1. The potential effects of tokenization apply to all the models, unless otherwise noted.

IV. Tokenization and Frictions in the Lifecycle of an Asset

This section discusses the potential impact of the features of tokenization on frictions along the lifecycle of a financial asset. This section focuses on a qualitative discussion, which considers, at each stage of the lifecycle, how tokenized ledgers would change frictions as compared with the prevailing financial market structures. In addition, Box 2 provides a summary of the small but growing empirical literature aiming to quantify the impact of tokenization on financial market frictions.

A. Asset Issuance

Asset issuance requires the creation of records of a firm's bond and shareholders. In the prevailing market structures, this process involves intermediaries known as registrars. These are often banks or trust companies. The need for such intermediaries arises because of economies of scale: by managing the recordkeeping and large volumes of transactions toward investors of many firms, these intermediaries incur lower transaction costs compared to a company that would choose to keep the records on its own. However, these intermediaries have operational costs and charge transaction fees.

A shared and programmable ledger can reduce some of the transaction costs from asset issuance. On a shared ledger, no separate record of asset owners is needed because every asset is linked to the account of the owner that purchased it. The services of a registrar are therefore not required, saving on issuers' transaction costs (Cohen and others 2018). Similarly, in the case of the issuance of native tokens, cost savings could arise from the fact that custodian services would not be required. Furthermore, programmability could reduce certain asset issuance costs. For instance, smart contracts could be used

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[12] Tokenization may reduce the costs of the processes performed by intermediaries rather than overcoming the need for intermediaries altogether. How much of the cost reductions in the processes performed by intermediaries will be passed on to investors will then depend on the degree of market competition.

to bring greater efficiency to auctions for new shares that are currently distributed by underwriters to their institutional clients (Omar and others 2021). Smart contracts could automatically execute auction rules once predefined conditions are met, reducing the time and resources needed to manage and execute the auctions. Programmability could also enable data to be wrapped into the token asset, which could aid transparency (that is, reduce information search costs) toward potential investors by facilitating access to information on the asset or issuing company, particularly for small-value issuances. For example, in 2022, BNP Paribas distributed a renewables project finance bond in tokenized form, embedding bond term sheet and environmental, social, and governance data in the token, which the bank argued improved transparency for this small-scale project finance initiative.

B. Asset Trading

Asset trading is subject to several frictions. These frictions originate from the need to overcome counterparty risks and limit search frictions, as well as from data processing costs.

Although financial intermediaries, including CCHs and CSDs, currently mitigate counterparty risk, they impose fees, thereby increasing the costs of conducting transactions on financial markets. Even if these financial intermediaries do not strive for profit, their cost recovery will necessitate transaction fees. These costs include the staff, equipment, and office space, and for a CCH that also acts as a central counterparty to derivatives trade (that is, a CCP) there can be costs associated with absorbing counterparty risk.

Shared and programmable ledgers offer a route to overcome counterparty risk on immediate trades through simultaneous settlement, without reliance on a financial intermediary.[13] When funds and assets are placed on a shared ledger where programmability enables parties to write smart contracts, a smart contract for the exchange of funds and an asset can be written, where the condition for executing the trade is that both the funds and the asset have been locked in place, ready for automated exchange, or otherwise the assets revert to the original owner. This ensures the simultaneity of delivery versus payment.[14] Such automation could result in transaction cost savings (see, for example, Benos and others 2022). Relatedly, a shared and programmable ledger can facilitate further ways in which transactions can be bundled, thereby minimizing counterparty risks from consecutive transactions. For instance, a transaction to lend an asset against local currency liquidity, then swapping the proceeds for another currency, and purchasing a foreign asset can be bundled into one so that it happens only if and when all currencies and assets are available.[15]

However, sharedness and programmability cannot mitigate counterparty risk stemming from the possibility that one party to the contract may fail to meet its obligations between the contract's initiation

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[13] Note that a CCH may have additional functionalities beyond contributing to address counterparty risk, such as dispute arbitration (Perino 2002) and the monitoring and management of collateral of open positions to ensure sufficient coverage for the associated risks (ECB 2005). Such functionalities could necessitate the continued presence of an intermediary, even if its scope could be more limited under tokenization (that is, if ensuring that transacting parties have sufficient funds to meet their obligations is no longer required). The same could be the case for other intermediaries.

[14] Simultaneity of exchange and settlement could still fail in a shared and programmable ledger because of operational risk events, such as cyberattacks. These risks are also present when trades are performed through traditional financial intermediaries.

[15] Package trade, a transaction that involves the execution of two or more component transactions in financial instruments where the execution of each component is simultaneous and contingent upon the execution of all the other components, does take place in current financial markets, with settlement managed by broker-dealers, centralized clearinghouses, and trading platforms such as stock exchanges.

and the time when future transactions are expected to occur. For example, if one party writes a derivative contract for the future delivery of an underlying asset conditional on certain events (such as a price level being reached), there is a risk that this party reneges on its obligations between the writing and the potential future execution of the contract, leaving the counterparty with losses. Most derivatives markets employ a CCP that ensures the execution of trades even if one of the parties reneges. There are two potential routes to address this form of counterparty risk on tokenized ledgers: either an intermediary (that is, a CCP or a trusted financial institution that guarantees its clients' repayments) is employed or all assets are locked in (by a program) for the duration of the contract. The latter would imply that a party that wishes to sell, for example, an option on a stock, would need to provide the stock at the time that the option contract is sold and have this collateral locked in place until the option expires or is executed.[16] Although this method would allow for trading without counterparty risk, it could be perceived as costly by investors (as a result of collateral lock-in) and reduce the incentives to write and trade derivatives contracts.

A shared ledger can also enable instantaneous settlement, potentially reducing frictions to transaction speed (constituting a transaction opportunity cost). Whereas simultaneous settlement refers to trades in which both legs are settled at the same time, instantaneous settlement means that settlement takes place immediately once a trade has been agreed upon. Even in cases where counterparties desire to perform an instantaneous trade, for a CCH to clear trades with broker-dealers, it can currently take up to several business days (shortened to one day in the US since May 2024). Delays in the current system are the outcome of having to synchronize multiple ledgers, including asset/money accounts at brokers and asset registration at a central custodian. Synchronization typically involves manual processes, which translate into transaction costs. A ledger that is shared by all participants may be programmed not to require manual synchronization, allowing for the reduction of time delays. The availability of faster settlement options can improve capital allocation. For instance, for transactions involving collateral, shortened settlement cycles can reduce the amount of time that collateral is locked, enabling better liquidity management.[17] In this sense, transaction settlement speed constitutes a friction that is part of the transaction cost category (namely, an opportunity cost).

A shared and programmable ledger can reduce search frictions on specialized markets with limited liquidity. An example is certain over-the-counter (OTC) asset markets, on which many types of bonds, derivatives, and foreign exchange are traded. OTC markets are facilitated through networks of broker-dealers that intermediate the market. The broker-dealers act as market-makers by quoting prices at which they are willing to buy and sell a financial asset. A shared digital ledger to which investors have direct

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[16] For certain types of derivative transactions, there is no specific asset to be locked away, and therefore this form of addressing counterparty risk may not be feasible. For example, an interest rate swap, which is an agreement to swap income streams referencing unknown future rates. In this case, it is not possible to calculate a collateral amount that would fully cover the exposure.

[17] The benefit discussed in this paragraph regarding faster settlement pertains to the length of time between the moment the buyer (seller) submits the payment (asset) and the moment the buyer receives the asset (payment). This is distinct from the interval between the time the contract is agreed upon and the moment the asset or payment has to be provided. Shortening this interval comes with pros and cons. On the one hand, a shorter time frame can reduce the gap between exposure calculations and the settlement of variation margin (Choudhury and others 2023). On the other hand, a larger time window enables investors to sell assets that they do not yet own or buy assets before they have the needed funds. With instantaneous settlement in this respect, assets and funds have to be "prepositioned" for a trade to occur (Lee 2021; Lee, Martin, and Müller 2022), potentially by intermediaries rather than the contracting parties, and potentially in the form of collateral. In addition, when investors are limited to only sell financial assets that they already hold, there can be unintended consequences on the informational environment, through the partial revelation of a trading history, which can have adverse consequences on market liquidity (Lee, Martin, and Townsend 2024).

access could facilitate finding a counterparty to perform a trade, potentially reducing the need to rely on financial intermediaries, such as broker-dealers. This could reduce the cost of trading on such markets (for example, the bid-ask spread charged by broker-dealers).[18]

C. Asset Servicing and Redemption

Transmitting payments to the owners of a company's financial assets currently involves a transaction cost friction. When firms need to make interest, principal, or dividend payments, they need to know who the bond and shareholders are. As discussed, the recordkeeping of a firm's bond and shareholders is typically performed by registrars, which have operational costs and charge transaction fees.

The services of collection and distribution of dividends and interest payments could be automated on a shared and programmable ledger, reducing the associated costs. As said, on a shared ledger no separate record of asset owners is needed because every asset is linked to the account of the owner that purchased it. Moreover, through the application of smart contracts on a programmable ledger, tokenized assets can embed asset servicing. A program could specify a given asset token how many money tokens to service and when, and this could be made conditional on the funds made available (such as a dividend distribution decision) of a company. Such automation would bring about a reduction in the costs of asset servicing activities.

Box 2. Estimates of Tokenization's Impact on Financial Asset Market Frictions

The measurement of the impact of tokenization is a novel field of research. This box summarizes the findings from several studies that quantify gains from financial asset tokenization.

Allen and Wittwer (2023) estimate the impact on asset trading costs from centralizing OTC bond markets, which relates to the sharedness feature of tokenization. The authors use transaction level data on the trading of sovereign (federal) bonds in Canada. Institutional investors' transactions can either be executed OTC through brokers or directly on a centralized ledger that is owned by the brokers. They find a central role for broker market power in explaining the observed market structure, wherein only a subset of institutional investors uses the ledger and the costs of ledger use remain relatively high. Estimating a counterfactual wherein institutional investors have no switching costs between brokers, they find that welfare gains from trade to institutional investors increase by up to 27 percent, because of both increased competition between brokers and investor ledger entry.

Pintér and Üslü (2022) estimate a structural search model on transaction data from the UK sovereign and corporate bond markets, which trade OTC rather than on a centralized ledger. Their aim is to quantify welfare losses that arise from decentralized asset trade, because of both broker market power and settlement delays. Their identification strategy centers on the cross-market variation of trading outcomes for clients who are active in both government and corporate bond markets. Welfare losses are estimated at 7.8 and 12.2 percent in government and corporate bond markets, respectively, and arise primarily from settlement delays on the corporate bond market and from a combination of such delays and broker market power on the government bond market.

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[18] Note, however, that over-the-counter markets may facilitate trading in, for example, nonstandardized instruments or complex derivative transactions requiring capital allocation from broker-dealers.

Box 2 (*continued*)

Onyx (J.P. Morgan) and Apollo (2023) provide a back-of-the-envelope quantification of one type of friction reduction that relates to programmability, namely the automated portfolio deployment of cash. By improving the ability of portfolio managers to continuously reinvest and thereby reduce cash holdings, this is estimated to result in a 24-basis point reduction (from an average of 1.09 percent to 0.85 percent) in the portfolio management fee to investors (assuming a full pass-through of managers' benefits to investors).

Leung and others (2023) estimate the impact of bond tokenization on asset issuance and trading frictions. Leung and others (2023) collect data on tokenized bonds and create different matched samples (using propensity scores) of conventional bonds with similar characteristics (namely, issuer, issue date, currency, maturity, size, and credit rating). The authors find that the underwriting fees of issuing a tokenized bond are, on average, 0.22 percentage points lower relative to conventional bonds. In addition, investors value the benefits of tokenization and are willing to accept a yield spread 0.78 percentage points lower for tokenized bonds. Similarly, the liquidity of tokenized bonds is found to be larger than that of matched conventional bonds. Bid-ask spreads of tokenized bonds are 0.035 percentage points lower than those for conventional bonds. All these effects are economically significant. The reductions in underwriting fees, yield spreads, and bid-ask spreads represent 25.8 percent of average underwriting fees, 23.9 percent of average yield spreads, and 5.3 percent of the average bid-ask spread of matched conventional bonds, respectively.

Liu, Shim, and Zheng (2023) estimate the impact of asset-backed securities (ABS) tokenization on issuance costs. They use data on 5,000 ABS issued in China and apply coarsened exact matching techniques to examine the pricing of blockchain-based ABS relative to comparable traditional ABS. The authors find that yields for newly issued blockchain-based ABS are on average 25 basis points lower than for traditional ABS. The yield differential varies depending on the type of underlying asset and the familiarity of key trading parties.

[1] The studies considered here are not intended to provide an exhaustive list of the literature that is related to features of tokenization. This note refers to studies cited within the papers discussed in this box for additional references. Note that the focus of the box is on empirical studies on the tokenization of financial assets. Empirical literature on the tokenization of non-financial assets is still scant at this stage, but the reader can refer to Swinkels (2023) and Tian and others (2020) for early studies on this topic. Lastly, note that the definition of tokenization used by the papers cited in this box differs from the one adopted by this note: it is this note's definition that is consistently applied to the content of the papers.

[2] An important limitation of this study is that results are based on a very small sample. Although the authors apply small sample statistical testing methods, the results should be interpreted with caution.

V. Tokenization and Externalities, Internalities, and Market Power

This section considers how the features of tokenization affect the extent of market inefficiencies caused by externalities, internalities, and market power. As before, existing market structures and regulations are taken as given and the section asks what change in market inefficiencies (compared to those prevalent in the current status quo) would come about by the adoption of tokenized ledgers.

A. Shock Transmission Externalities

High leverage, low funding liquidity, and interconnectedness amplify the transmission of shocks among financial intermediaries, exacerbating externalities and adversely affecting financial stability. Financial institutions do not have incentives to internalize the transmission of shocks to each other and related financial stability implications when deciding on their funding structure and connections (within regulatory boundaries). When a financial institution is highly leveraged, it has greater incentives to take risk. Possessing a small equity stake relative to its issued debt allows the institution to fully benefit from the potential profits that such risk-taking may render, while if the institution goes bankrupt, some of the losses would be borne by creditors (and/or the public sector in the case of bailouts), thereby imposing negative externalities on other market participants and/or taxpayers. Moreover, highly leveraged institutions, whose equity is small relative to the size of their balance sheets, have fewer buffers to withstand shocks. Similarly, institutions with low levels of funding liquidity may be forced to sell illiquid assets in the event of a shock, potentially leading to declines in the values of such assets and to financial losses. Risks to the financial system are amplified when leveraged financial institutions and/or institutions with low levels of liquidity are significantly interconnected with each other. A domino effect may occur when a shock pushes one institution into bankruptcy, leading it to default on its obligations to other interconnected financial institutions. These, in turn, may themselves be highly leveraged or lack sufficient liquidity and thus have limited capacity to withstand the shock.

Tokenization may increase the spread of shocks across financial institutions, undermining financial stability. This relation depends on whether and how tokenization affects leverage, funding liquidity, and interconnectedness. It also depends on tokenization’s influence on the speed with which shocks are able to spread, because greater speed increases the difficulty for policymakers in mitigating the effects and costs associated with externalities.

A shared and programmable ledger can reduce the cost of leverage, consequently strengthening the incentives for financial institutions to lever up. As discussed qualitatively in Section IV.A and quantitatively in Box 2, tokenization has the potential to decrease the cost of asset issuance. Both Leung and others (2023) and Liu, Shim, and Zheng (2023) find lower costs associated with the issuance of tokenized bonds compared to conventional bonds. A permanent reduction in the cost of debt issuance could render leverage more appealing for financial institutions (holding capital requirements and other regulations to mitigate excessive leverage constant and assuming these are not binding). However, the impact will depend on how sensitive leverage incentives are to issuance cost reductions. Programmability could also facilitate the leveraging of intermediary balance sheets through so-called rehypothecation, whereby assets that are used as collateral to secure a transaction are further used by the intermediary arranging the transaction: tokens received as collateral could be automatically rehypothecated using smart contracts (FSB 2024). Should leverage increase, this could raise the potential for externalities and financial stability risks. This scenario illustrates how mitigating one inefficiency, in this case, transaction costs, could inadvertently amplify another, such as externalities.

Tokenization may affect funding liquidity and increase the spread of shocks if financial institutions' reliance on retail deposits becomes harder to sustain. Financial institutions generally fund themselves either with (insured) retail deposits or through market-based (wholesale) funding. The former are considered more stable than the latter. If a shared and programmable ledger reduces the costs of investing in financial assets other than bank deposits, retail depositors may increase their share of funds invested in such securities. Under these conditions, the availability of retail deposits would decline, and financial institutions could find themselves more reliant on wholesale funding. Such funding is more likely to dry up at the same time that a shock hits the market (Brunnermeier and Pedersen 2009), exacerbating the likelihood of default and associated knock-on effects.

A shared and programmable ledger can lead to increased interconnectedness, resulting in heightened shock transmission externalities. A larger number of investors having cheaper and faster access to a wider set of markets and assets (as a result of the removal of frictions that underpin transaction costs) can lead to greater interdependencies within the financial system. Higher interconnectedness may magnify the externalities of market participants on each other and/or the public sector stemming from economic shocks (the domino effect discussed previously).[19] Programmability facilitates the construction of complex assets, whose returns may depend on several underlying assets or on the settlement of several preceding transactions. Composed assets (whose label reflects that they are composed of other assets) are, by their nature, interconnected to other assets. Increased sharedness facilitates access to these interconnected assets by a larger set of investors.

One way that increased interconnectedness can amplify shocks is by expanding the number of assets with values pegged to other assets or currencies. A pegged instrument or an intermediary offering a fixed-value claim has broader interlinkages when an instrument is used as collateral in other transactions or when an intermediary has borrowed funds from other intermediaries. In such cases, a run on one instrument or intermediary can precipitate a broader crisis of confidence in financial markets or institutions.[20]

A widely shared ledger can increase trading speed, potentially amplifying the velocity and intensity of shock transmission. Leveraged intermediaries have the potential to face runs, which involve many investors quickly and simultaneously trying to remove their funds or sell their assets. These developments display cascading dynamics, as the observation of such events induces even more investors to rapidly withdraw or sell. Under such circumstances, separate ledgers can function as inadvertent dams to the

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[19] There exists a large literature on the role of interconnectedness in financial stability. See, for example, Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015), Roncoroni and others (2021), and Ghio and others (2023).

[20] One example is stablecoins that offer a fixed redemption value against, for instance, US dollars. These could experience runs because of uncertainty about the credibility of the redemption promise (for instance, if they lack verifiable reporting on their underlying assets). For case studies of stablecoin runs, see, for example, IMF (2021), Uhlig (2022), Briola and others (2023), Kosse and others (2023), and Anadu and others (2024).

flow of funds, as time is needed to transfer information between ledgers that are not interoperable. Shared ledgers may remove such dams.[21,22]

By facilitating automated trading behavior, a programmable ledger can increase trading speed, and thereby increasing the velocity and intensity of shock transmission. Automated trading entails the use of systematic and rule-based algorithms to execute trades.[23] Extreme market volatility induced by automated trading behavior, often referred to as a flash crash, has already been observed in present-day markets (Kirilenko and others 2017). By enhancing the programmability of ledgers, tokenization could exacerbate the risk of such events. This could happen, for example, by having chains of smart contracts written to be contingent on one another across a broader range of assets and extending access to these contracts to a larger user base.

B. Market Infrastructure Investment Externalities

Increased sharedness and programmability have the potential to raise the costs associated with market infrastructure investment externalities if they make trading faster or lead to increased interconnectedness. Counteracting operational risk on a ledger requires significant investment, including a multilayered security approach that includes encryption, authentication, access controls, and monitoring. If a ledger is operated by one or multiple private parties, who bear only part of the total cost incurred by all ledger participants from operational risk events, then they could have incentives to underinvest in operational security. The costs associated with such events have the potential to rise under tokenization. Any digital system faces a certain probability of failing. Programs can fail because of software errors, unexpected human behaviors, or the malicious intent of illicit or fraudulent actors (Lavayssière and Zhang 2024). The aggregate effect of a malfunction in one transaction depends on how many other transactions are affected by it. The increased interconnectedness and number of users (sharedness) who can be associated with tokenized ledgers (discussed in Section V.A) can magnify the effects of failures. Moreover, increased sharedness can come with a concentration risk because a widely shared ledger can become a single point of failure to cyberattacks. A dominant central role for a single financial market infrastructure implies a more widespread potential disruption should that infrastructure experience a disruptive cyberattack.[24]

C. Network Externalities

Market liquidity and innovation incentives are subject to externalities that can be affected by the sharedness and programmability of a ledger. A network externality (also known as network effect) occurs

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[21] One example is the transfer of funds from one bank to another in the US, as traditional bank transfers are not instantaneous. Although funds can be instantaneously transferred (from the users' perspective) through financial intermediaries such as Zelle or Venmo, such transfers have amount limits. Instantaneous bank transfers can also be made through FedNow, an instant payment infrastructure developed by the Federal Reserve. However, uptake by banks is not complete.

[22] Depending on their design, central bank digital currencies may also affect run risks for the financial sector (Mancini-Griffoli and others 2018; Agur, Ari, and Dell'Ariccia 2022; Gross and others forthcoming).

[23] Automated trading is common in stock exchanges (for example, New York Stock Exchange), futures and options exchanges (for example, Chicago Mercantile Exchange), and foreign exchange markets, among others.

[24] In permissionless ledgers, however, a larger number of users generally increase the value of the (settlement) asset used to reward transaction validators, attracting more validators, and increasing the network's security.

when the value to an individual agent of taking an action depends on how many other agents take the same action. Participation in a ledger constitutes such an externality when the extent of market liquidity, which is of value to all market participants, depends on how many users the ledger has. That is, an individual investor or issuer's decision to join a ledger can depend on how many other investors and issuers have decided to join.

Sharedness and market liquidity are closely related as the increased use of a shared ledger implies that more buyers and sellers are brought together. For instance, if an OTC market is moved to a shared ledger, the liquidity of that market could improve as a result of the offering of standardized contracts, the increased clarity of market pricing information (that is, having the buy and sell offers centrally quoted rather than bilaterally contracted), and the lower search frictions caused by all agents trading on the same ledger. Liquidity, in turn, is closely related to transaction costs.[25] For instance, bid-ask spreads tend to shrink as market liquidity increases. Lower transaction costs may also incentivize more users to join the ledger, carrying the potential for a virtuous cycle of increased sharedness.

The fractionalization of assets enabled by tokenized ledgers can further enhance incentives for retail investors to join such ledgers, increasing positive market liquidity externalities. The price of a single stock or bond can be hundreds of dollars, which can make it hard for small retail investors to access, particularly if they desire to diversify. Asset fractionalization refers to the splitting of assets into smaller pieces and can be provided to retail investors either by ledger design or by financial intermediaries. Currently, only a few intermediaries, such as Robinhood and Fidelity, enable asset fractionalization.[26] While Robinhood and Fidelity offer US-domiciled equities to investors in fractionalized form, they do not offer fractionalized bonds or fractionalized international equities.[27] Moreover, where intermediaries do provide such services, this may come with an added risk to investors: even if the fractional offering is fully collateralized in terms of underlying assets, the bankruptcy of a broker could imply a lengthy period to recover the value of fractionalized assets.[28] Fractionalization can also be attained by design in new ledgers where assets can be issued in tokens of arbitrarily small value. If the tokens are offered directly by the issuer, there is also no intermediary risk involved in holding a fractionalized asset on such a ledger.

However, should interest in tokenization cause a proliferation of noninteroperable ledgers, this could lead to a decrease in market liquidity and therefore reduce the beneficial network externalities. If several competing and noninteroperable new asset trade ledgers are launched, and assets and users end up segmented across ledgers, then fragmented trading could result. This risk is particularly pertinent when ledgers are set up by private entities and there is a lack of coordination and regulatory requirements to ensure interoperability. The segmentation of market participants across several ledgers could lead to lower liquidity (and, relatedly, higher transaction costs and search frictions) than in current financial markets. An example of such liquidity bifurcation in practice is provided by Allen and Wittwer (2023) and is discussed in Box 2. A proliferation of noninteroperable ledgers would represent a decrease in

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[25] For example, joining primary and secondary markets on the same ledger may facilitate trading (OECD 2020).

[26] To an extent, Exchange Traded Funds (ETFs) perform a similar function (allowing retail investors to buy a complete portfolio of assets), although an ETF has a pre-determined allocation, which cannot be determined by the retail investor, if she wishes to do so. Securitization also shares some features with the fractionalization of assets enabled by tokenization (Chang 2020).

[27] For a discussion and empirical analysis of equity fractionalization in the US, see Bartlett, McCrary, and O'Hara (2024).

[28] In the US, the Securities Investor Protection Corporation insures retail investors' securities and cash at brokerage firms up to a limit, and would be involved in the resolution process of a failed broker.

sharedness. Therefore, the risks discussed in this paragraph emanate from a weakening rather than a strengthening of the features that define tokenization.

D. Knowledge Externalities

The benefits from the creation of new knowledge are not always fully appropriated by the innovator, resulting in positive externalities to other agents. For instance, open code developments can be used by anyone, allowing agents to benefit from new programs without incurring development costs. For this reason, innovators have incentives to invest in new knowledge to an extent which is lower than socially desirable. The strength of knowledge externalities also depends on the size of the market. The larger the number of users of the platform (sharedness), the greater the social benefits from new knowledge creation, and the greater the potential for the innovator to profit from creating new knowledge.

More shared and programmable ledgers provide a common infrastructure for developers to build on and ease the path for innovations to attain critical mass. A larger shared user base strengthens private companies' incentives to invest in such innovation.[29] Moreover, when more investors and asset issuers share a programmable ledger, there is a broader set of contingent actions that can be automatically executed, which could expand the universe of contractual outcomes (Townsend and Zhang 2023).

Whether or not the code of a ledger is publicly accessible can affect knowledge externalities related to innovation.[30] Open code access can be either a boon or a bane for innovation incentives. Open code access facilitates building improvements on top of work produced by others, which can reduce the cost involved in developing new products and services. However, open access also reduces the potential benefit of investing in research and development because companies foresee that their own code could quickly be copied or improved upon by others, leaving less scope to monetize the innovation.[31]

E. Retail Investor Internalities

To the extent that direct trading by retail investors is allowed on these ledgers, it has the potential to exacerbate internalities. Retail investor internalities arise when they do not fully comprehend the risks associated with an asset. When trading with brokers, retail investors generally have the option to request the services of a financial adviser.[32] With direct trading, investors could still seek the advice of independent financial consultants, but this may entail an additional search effort, reducing the incentives to hire such services. Should retail investors resort to direct trading without advice, there could be increased costs associated with internalities from purchasing financial products that advertise high returns and whose risks they do not fully comprehend. Moreover, unadvised retail investors may be more likely to insufficiently diversify away idiosyncratic risk in their portfolio. While ill-advised or unadvised trade exists

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[29] One example would be a new smart contract that streamlines the implementation of auctions for stock issuances. A ledger with a limited number of users might not offer sufficient incentives for the development of such a smart contract.

[30] On permissionless DLT systems (discussed in Box 1 and Annex 1), the code is necessarily publicly accessible.

[31] Licensing or patenting might prevent users from copying or using the code developed by others to create enhancements. However, these measures would also limit the benefits associated with open-source code.

[32] Financial advisors can provide unsound advice too. Nevertheless, the odds of appropriate investment strategies when engaging the average financial advisor are likely higher than when the average retail investor deploys her own strategy.

on traditional brokered markets too, its occurrence could be greater if direct trading occurs on tokenized ledgers, unless appropriate regulations are put in place to guarantee adequate consumer protection.

Internalities are likely to increase when the ledger offers a greater ease of constructing complex products through programmability. Costs associated with retail investor internalities are especially likely to occur when transacting with complex assets, such as derivatives, whose market value can depend on multiple variables and states of the world. Instances have occurred where investors faced sizable and unexpected losses from derivative contracts that they did not fully comprehend (for example, Storbeck 2023). Increased programmability can make it easier to create complex assets, thereby compounding the costs associated with internalities, particularly if retail investors engage in direct trading on tokenized ledgers.[33]

Tokenization on permissionless distributed ledgers can come with larger costs associated with internalities. Regulatory and legal rulings are particularly difficult to enforce in permissionless distributed ledgers because of their decentralized governance structures, for instance, regarding the reversal of fraudulent/illicit transactions. This implies that mitigating risks to retail investors could be more challenging.

F. Market Power Inefficiencies

Switching costs and barriers to asset trade can uphold broker rents by stifling broker competition. Established intermediaries in asset trade can profit off the market power derived from separate ledgers that make it costly (in terms of time, effort, and sometimes required fees) for retail investors to switch to the services of another intermediary. For instance, if a retail investor currently wants to switch brokers in the US, the services of a special clearinghouse that allows in-kind transfers of assets are required. This clearinghouse is called an automated customer account transfer service (ACATS). The investor needs to fill out a transfer initiation form with the receiving broker, with information that matches the records held at the old broker, and share the latest account statement. The new broker contacts the old broker, and they initiate the transfer through ACATS. The process typically takes between three and six business days. The time and effort involved discourages retail investors from changing brokers in search for lower fees. In turn, this subdues the incentives for brokers to reduce fees with the aim of attracting new clients.

On a shared ledger, the transfer and reconciliation of data between brokers could become instantaneous, reducing the costs involved in switching and harnessing competition to bring about lower brokerage fees. On a shared ledger, every broker could immediately verify every other broker's record, because the information about the assets on these records could be made instantly accessible. A transfer of assets could then be implemented directly and without the need for a clearinghouse. This could lead to two types of cost reductions as compared to the current financial market structures. First, the costs of operating a clearinghouse can be saved and such savings may find their way to lower transaction costs for retail investors. Second, the increased ease of switching would result in competitive pressure on brokerage fees. For instance, new entrants in the brokerage business could attempt to quickly gain market share by undercutting the fees charged by established brokers.

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[33] Regulated tokenized ledgers could enable direct trading by retail investors subject to certain constraints, whose enforcement may be facilitated trough programmability, in the same way that today, for example, there are restrictions on who can sell option contracts (currently, retail investors can buy stocks and may be able to buy simple options, but they are not allowed to sell options).

Competitive pressure to limit brokerage fees could also arise if the shared ledger enables direct trading by retail investors or allows them to purchase assets directly from issuers. In the currently prevailing structures for financial asset markets, this is generally not possible. Although there are some exceptions, such as TreasuryDirect, which allows US residents to purchase debt directly from the US Treasury, retail trading is generally required (by regulation) to be done through brokers.[34]

Even when direct trading is possible, brokers may well continue to execute most trades, although possibly at lower fees. An empirical case study that speaks to the continued role of brokers in directly accessible markets is provided by Bergquist, McIntosh, and Startz (2024). They study the introduction of a mobile-phone accessible trading ledger offered to farmers in Uganda. The ledger can directly match the buyers and sellers of agricultural commodities. They find that, despite the ease of access, very few small farmers choose to directly trade on the ledger. Instead, the same agents that intermediated trade before the introduction of the ledger continue to do so afterward. Nevertheless, the trading fees charged to the small farmers do decline: their outside option to forego the intermediaries and trade directly raises the competitive pressure on the intermediaries, which leads to the decline in fees.[35]

Tokenization can also affect market power inefficiencies by a different route: if the ledger is privately owned, the owner(s) could extract monopoly rents. The more shared and dominant a ledger is, the larger the market power of its owner(s) may be. The ledger owner(s) would have privileged access to data, which could be used to increase profits, for instance, through data sales or direct credit provision (Agur, Ari, and Dell'Ariccia 2023a).[36] Market power could also be monetized by charging fixed or variable (for example, per transaction) fees for firms or households that wish to be active on the ledger. One strategy could be for a private provider to initially establish the ledger with free access and, once dominant, begin to charge fees. Network effects, setup costs, and returns to scale can function as barriers to entry that prevent other private ledgers from challenging the dominant position of the fee-charging ledger by undercutting its fees.[37]

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[34] Access to direct trading on the New York Stock Exchange (NYSE), which enables investors to execute trades by directly interacting with the trading platform's electronic order book, is restricted to the broker-dealers registered with the Securities and Exchange Commission with self-regulatory organization status and established clearing firm connections. Retail investors are explicitly excluded from direct NYSE membership and trading capabilities. Instead, individual investors must rely on brokerage firms to execute trades on their behalf, with these firms acting as intermediaries between retail clients and the exchange. Some brokers may offer more advanced routing options or trading platforms, but true direct access to NYSE trading systems remains unavailable to typical retail investors.

[35] Furthermore, as discussed in Box 2, despite the presence of a centralized ledger with direct access, intermediaries can nevertheless sometimes retain market power derived from client relations and continue to conduct bilateral trades with other intermediaries on their clients' behalf outside of the ledger.

[36] Traditional trading platforms such as exchanges face regulatory requirements on data usage. Examples include the General Data Protection Regulation (GDPR) in Europe and the California Consumer Privacy Act in the United States. Moreover, regulatory bodies such as the Securities and Exchange Commission and the Commodity Futures Trading Commission impose requirements for reporting trades to ensure transparency in the United States.

[37] A private ledger with significant market power can also lack the incentives to invest sufficiently in the infrastructure that is needed for rural or poorer populations to obtain access (Brunnermeier, Limodio, and Spadavecchia 2023).

VI. Conclusion

This note adopts a broad and technology-neutral definition of digital token ledgers and tokenization. The key defining features of digital token ledgers are sharedness to allow ownership transfer, programmability to execute contingent transactions, and trust by participants in the system's integrity for users to willingly transact on the ledger.

This note provides a conceptual framework based on market inefficiencies to analyze how tokenization may affect financial markets and links each effect to changes in the specific features of token ledgers. It takes existing market structures and regulations as given when investigating the changes that tokenization could bring to market inefficiencies compared to the current status quo. The analysis is not circumscribed to a particular model of tokenization but rather applies to all, except when specifically noted.

The potential effects of tokenization stem from improved sharedness and programmability. These effects include further mitigation and reduced costs associated with easing frictions throughout the asset lifecycle by reducing the need for certain intermediaries, automating procedures, mitigating counterparty risk through simultaneous settlement, enabling faster settlement, and reducing search frictions. In addition, more shared and programmable ledgers may affect the degree and costs associated with externalities, internalities, and market power. On the positive side, they may result in increased innovation and liquidity externalities which could benefit the functioning of financial markets. At the same time, they may facilitate the spread of shocks across financial institutions, increasing financial stability risks. They could also augment the costs of operational risk events, exacerbate retail investor internalities, and affect market power. Further research is needed to provide a quantification of the benefits and risks associated with the impact of tokenization on market inefficiencies.

Regulations play a key role in addressing financial market inefficiencies, and they might need to be adapted to both harness the benefits and mitigate the adverse effects of tokenization. Such regulatory changes are beyond the scope of this note and are the remit of standard-setting bodies and financial sector regulators and supervisors around the world.

Annex 1. Ledger Design and Risks to Trust

Each of the three models to achieve trust—permissionless DLT, permissioned DLT, and single-operator systems—is exposed to different risks that may undermine the trust it generates.

DLT is a set of technological solutions that enables a single, sequenced, standardized, and cryptographically secured record of activity to be distributed and maintained by a network of participants (IMF 2023). This record can contain transactions, asset holdings, or identity data, among other data inputs. DLT may be closed (permissioned) or open (permissionless). On permissionless DLT ledgers, anyone can access the ledger's information and participate in the transaction validation process, as no central authority can approve or deny participation (Agur and others 2023b). For instance, anyone can download the free Bitcoin software to make a computer a Bitcoin node that can validate transactions. By contrast, on permissioned DLT ledgers, the participants must be certified by an entity or a consortium, prior to connecting to the network to read, write, or validate transactions.

In permissionless DLT systems, trust may fail as a result of attacks that overcome consensus mechanisms. These digital ledgers need to achieve consensus on the state and programming functions across the multiplicity of nodes. They usually rely on monetary incentives (Agur and others 2023b). The feasibility of a successful attack varies depending on the specific consensus mechanism employed by the network (Bains 2022). For instance, under proof-of-work consensus mechanisms, a successful attack requires the control of more than 50 percent of the computational power devoted to validating the network's transactions. Trust in the ledger is partially determined by the probability that it may suffer an attack.

Trust in permissionless systems may also fail because of the potential for users to extract value by exploiting pending transactions and the risks associated with incorporating off-ledger information. When a user posts a transaction on a permissionless ledger, a fee payment must be simultaneously submitted. Depending on the size of the submitted fee, the ledger's validators will decide where to position the transaction in the line of transactions pending to be validated. Because of profit maximization incentives, transactions with higher fees are generally validated first. This creates the potential for targeted price manipulations because attackers, by choosing the submitted fee for their own transaction, can target where in the validation queue to locate it, front-running others. For example, an attacker can "sandwich" a transaction by another user between two of its own, to make a profit (Park 2023). Moreover, in such ledgers, there is no central authority that incorporates information from the outside world. Applications that source, verify, and transmit external information to smart contracts running on a permissionless blockchain, known as oracles, generally assume this transmission role. However, they present vulnerabilities, accounting for a significant fraction of cyberattacks (Lavayssière and Zhang 2024). Imposing penalties for a lack of regulatory compliance is also more challenging on permissionless ledgers because of their decentralized governance structures (IMF 2023).

Instead, in permissioned DLT systems, trust could fail as a result of changes enforced by the network authorities. The authorities can, in principle, modify the records on the ledger at their discretion, including manipulating trading or prices for their own benefits. However, disincentives against such manipulations include the need to preserve their reputation, which allows the authorities to obtain future profits (if the ledger is private) or achieve policy goals (if the ledger is public). Regulatory measures and penalties for noncompliance also serve as significant deterrents against ledger tampering. A centralized ledger in this regard faces the same type of risks to trust as a permissioned DLT, but arguably to a greater degree as no consensus among permissioned authorities needs to be reached to modify the ledger or its programming functions.[38,39]

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[38] In practice, perceived risks to trust on a centralized ledger would largely depend on the credibility of the central authority. For example, if a central bank with an established reputation manages the centralized ledger, the reputational cost of revoking the asset owner's sole authority over the asset could be so large that users will attach a low probability to such actions.

[39] While a permissioned distributed ledger technology with multiple copies of the ledger may achieve more security relative to a centralized ledger with no backups, centralized ledgers generally do have multiple server backups.

Annex 2. Comparing Native and Non-Native Tokens

The distinction between native and non-native tokens is nuanced. Non-native tokens are defined as representations of assets external to the ledger. These are tokens whose unit of account is the off-ledger asset backing them. Examples include tokens representing an ounce of gold, a house, a painting, or a US dollar, each backed by the respective asset. If these backing assets are also traded in off-ledger markets, there is a possibility for price discrepancies between ledger and off-ledger markets. That is, token prices may decouple from the off-ledger prices of the assets they represent.

This contrasts with tokens that are issued only on the ledger and are backed by off-ledger assets that do not serve as their unit of account. These tokens are classified as native. An example is a stablecoin issued only on the ledger and denominated in US dollars but backed by off-ledger assets other than US dollars, such as government bonds or commercial paper. Although commercial paper and government bonds may be denominated in US dollars, they are not the currency itself and their value expressed in the currency changes over time. The stablecoin may lose its peg with the US dollar (or another asset to which it is pegged), preventing redemptions at par. Such de-pegging is not classified as a token decoupling.

These assets are only considered non-native if a given company issues the same asset (for example, money market fund shares) both on- and off-ledger, and the on-ledger assets are represented by the units of the off-ledger issues held in escrow. If the off-ledger asset and its on-ledger representation trade at different prices, this scenario is considered a token decoupling.

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