Economic impact potential of real-world asset tokenization *

Authors

Markuss Baltais [a], Evita Sondore [a]

Supervisors

Talis J. Putniņš [a, b, c], Jonathan R. Karlsen [c, d]

[a] *Stockholm School of Economics Riga*
[b] *University of Technology Sydney*
[c] *Digital Finance Cooperative Research Center*
[d] *University of Western Australia*

Tokenization of real-world assets (RWA) can fundamentally transform trading, custody, and settlement, removing many inefficiencies from existing markets. We estimate the total potential economic gain of RWA tokenization is around $2.4 trillion per annum globally from increased efficiencies. The largest gains in both proportional and absolute terms are in foreign exchange, driven by the existing inefficiencies, the size of the asset class, and the high turnover. Scaled back to the current trajectories for tokenization, we estimate realistic annual gross gains between $31 billion and $130 billion by 2030.

JEL classification: G14, G15, O16

Keywords: tokenization, financial markets, digital finance, distributed ledger

---

* Send correspondence to Tālis Putniņš, UTS Business School, University of Technology Sydney, PO Box 123 Broadway, NSW 2007, Australia; telephone: +61 2 95143088. Email: talis.putnins@uts.edu.au.

We thank Darren Younger from Bricklet, William Lin from Arcanite, and Dustin Weiss from ASX for their constructive comments and suggestions.

1. Introduction

Financial system evolution is often driven by technological advances. Tokenization of assets, that is, representing their ownership and properties in the form of secure digital bearer instruments, fundamentally transforms the process of trading, custody, and settlement. Real-world asset (RWA) tokenization is in the early signs of adoption and the subject of a large research and development effort from industry, central banks, and policymakers. The technological enablers are distributed ledger technologies (DLT), growth in computing power to enable DLT at scale, and the acceptance of digital signatures as a secure means of proving identity and claims in a digital environment. The economic potential of this innovation includes efficiency gains, increased automation from asset programmability, increased liquidity, and reductions in intermediation.

But how large are the potential economic gains from tokenization? Where are the largest benefits in the asset registry, custody, transfer, trading, and settlement processes? And which asset classes are most likely to benefit substantially from tokenization?

To address these questions, we develop a novel estimation approach. For each major asset class, on a global scale, we estimate the potential gross efficiency gains from tokenization by considering the impact of tokenization on the different categories of costs in the process of asset issuance, registry, trading, custody, and settlement. We multiply the annual percentage efficiency gains from the tokenization of different real-world asset (RWA) classes, with their market capitalization to obtain total potential dollar gains. We also produce scaled-back estimates by multiplying this total potential economic gain by the percentage of the asset class that may realistically be tokenized by 2030.

Our findings suggest that a full-scale RWA tokenization could yield gross economic savings of up to $2.4 trillion per annum. Considering that realistically only a fraction of the asset class can be tokenized, we estimate the likely realizable annual economic benefits to range from $31 billion to $130 billion, based on our projections for the extent of tokenization achievable by 2030. The scale of these efficiency gains is comparable to the shift from paper certificates to electronic records in the 1980s, and, as such, should incentivize policymakers to promote the adoption of RWA tokenization.

Savings achieved through tokenization vary widely across asset classes due to their differing characteristics (e.g., market size and inefficiency). For example, the foreign exchange (FX) market may gain $813 billion annually from tokenization due to its high daily trading volumes, large size, and numerous inefficiencies. In contrast, gains in real estate assets are lower due to the “uniqueness” (or “non-fungibility”) of the assets and because they generally feature high price-to-income ratios. Despite these challenges, the sheer volume of the real estate market amplifies even modest efficiency improvements yielding significant savings of up to $62 billion annually.

However, tokenization does feature risk mainly due to the technology’s reliance on blockchain or other forms of DLT. Rapid adoption raises concerns about the technology's capacity to keep up with the demands of widespread use including user-friendly platform design and advancing resistance to blockchain splits (or "forks"). Physical assets in tokenized form also require accurate recording of real-world changes. This creates a need for reliable oracles — systems that feed real-world data into the blockchain — which could come from various sources including monitoring services, government bodies, and online data providers. These sources need clear guidelines for setup, maintenance, and data interpretation to ensure accuracy and reliability (Uzsoki, 2019).

The initial savings from tokenization are just the beginning. Over time, as more assets are tokenized on a large scale, we can expect a ripple effect of benefits. This includes large-scale automation of financial services through smart contracts and the creation of more efficient and liquid markets. Additionally, tokenization could lower the costs of market infrastructure, enabling trade with new markets and making previously illiquid and hard-to-access markets more accessible. In our calculations, we deliberately exclude the cost side of tokenization to determine the peak magnitude of potential gains.

The tokenization of assets follows a history of financial market transformations that stem from changes in how asset ownership is represented. For example, the ownership of shares and other financial securities was for a long time tied to physical paper certificates, known as bearer instruments. These physical certificates were very flexible in accommodating trading, lending, and other financial functions, but inefficient and vulnerable to counterfeiting. Thus, with the arrival of computers, physical bearer instruments were largely replaced with centralized electronic records of ownership.

Centralizing the ownership records was necessary at the time (the 1980s) because computing power was unable to process the cryptographic signatures required to create digital bearer instruments (tokenized digital assets) at scale, nor were the technologies of secure digital signatures and distributed ledgers widely accepted. Tokenization of RWA is akin to returning to bearer instruments, with their upsides such as capital fluidity and enabling peer-to-peer intermediated transfers, but in digital form such that the issues of counterfeiting and paper-based settlement inefficiencies are eliminated.

Given the novelty of the topic, academic literature on quantifying the efficiency gains of RWA tokenization is very limited. To the best of our knowledge, this is the first study to attempt estimating these efficiencies across asset classes and at a global scale. The absence of research on this topic is likely because, unlike most research, which base their analysis on past data to uncover relations, full-scale RWA tokenization has yet to materialize. Consequently, any analysis in this domain is extremely challenging, requiring higher reliance on assumptions and approximations than most empirical studies. Our research therefore relies heavily on industry reports and expert opinions rather than historical data simply because there is none. To our knowledge, there is no other way currently to measure the total economic gains from tokenization than to estimate upper and lower bounds from current inefficiencies in financial markets. Our research contributes to the existing body of knowledge by offering a detailed overview of the tokenization processes, estimating the fraction of assets that are likely tokenized in the near future, and quantifying the global value of annual economic savings that RWA tokenization could yield.

Our paper is related to a small number of recent studies on this emerging topic including the viability of tokens to finance businesses (Howell et al., 2020), disrupt industries (Sazandrishvili, 2020), facilitate blockchain-based settlement (Chiu and Koeppl, 2019), fractionalize real estate (Baum, 2021), and improve competition in industries (Cong and He, 2019) and product markets (Chod and Lyandres, 2023). Our paper also relates to the literature on tokens to facilitate platform user adoption (Cong et al., 2021), productivity (Cong et al., 2022), financing (Gryglewicz et al., 2021; Chod et al., 2022), and mitigate platform exploitation of users (Sockin and Xiong, 2023). Previous studies (e.g., Chen et al., 2023) have also attempted to measure the value of FinTech more broadly but only through stock market responses to patent filings, a small subset of the total economic gains.

Law researchers study the corporate governance risks of tokens (Blemus and Guégan, 2020), risks inherent in tokens with no cash flows (Schwarcz, 2022), property rights of token holders (Woxholth et al., 2023), which law should govern token ownership (Fairfield, 2022), issues in digital security issuance and transfer (Layr, 2021), and legal viability of tokenized real estate transactions (Garcia-Teruel and Simon-Moreno, 2021). Related studies in computer science and engineering include the potential for tokenization to enhance the post-trade processing of assets (Ross et al., 2019), create asset-backed tokens (Li et al., 2019), improve medical record sharing (Liu, 2016), finance infrastructure development (Tian et al., 2020) and be adopted by businesses (Heines et al., 2021).

2. Asset tokenization and categories of economic impact

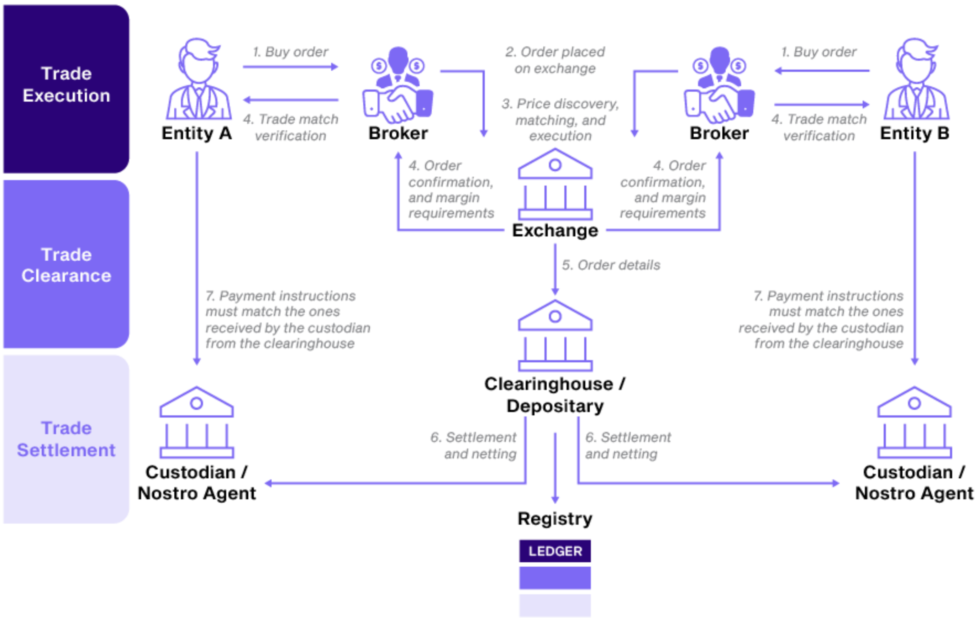
Tokenization of real-world assets involves representing the rights of ownership of off-chain assets with digital tokens on a blockchain or a similar distributed ledger. This process ties an asset's characteristics, ownership rights, and value to its digital representation. In other words, the token serves as a digital bearer instrument which allows the owner of the token to claim ownership of the corresponding asset.

In the past, ownership of assets was denoted by physical bearer certificates, which, despite their utility, were susceptible to theft, loss, forgery, and money laundering. With the advent of computers in the 1980s, the concept of digital bearer instruments emerged, promising to eliminate the drawbacks of physical certificates. However, the realization of digital bearer instruments was hindered by the lack of advanced computational capabilities and sophisticated cryptographic algorithms. Consequently, the focus shifted towards centralized electronic registries that maintained digital records of asset ownership. While these dematerialized assets improved efficiency, their centralized nature necessitated reliance on various intermediaries, introducing additional costs and inefficiencies. The development of Distributed Ledger Technology (DLT) has now made it feasible to revisit the concept of digital bearer securities, or tokens.[2]

DLT is a collection of protocols and frameworks enabling separate computers to propose, validate transactions, and maintain synchronized records in a network (Bech and Garratt, 2017). This technology decentralizes record-keeping, shifting the responsibility away from a single central authority. This decentralization not only reduces the administrative burden but also lowers the risk of system failure associated with reliance on a central entity, thereby enhancing the system's resilience (see Figure 1).

[2] DLTs provide the necessary computational power and complex cryptography to overcome the limitations of earlier systems.

Panel A: Current market structure with a clearinghouse.



Panel B: Digital market structure with consensus process.

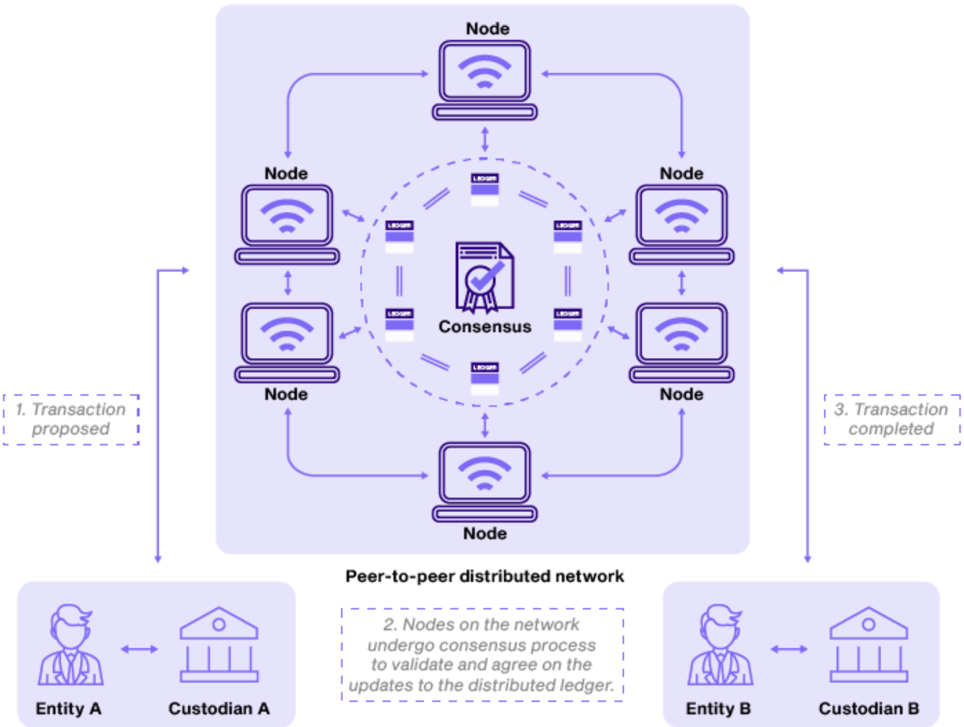


Figure 1
Transitioning to a DLT-based market structure.
This figure illustrates the transaction process via the current system (Panel A) and a DLT-based system (Panel B). In Panel A, there are a multitude of intermediaries involved in the trade execution, clearing, and settlement. In Panel B, execution, clearing, and settlement are carried out through a consensus process as an intermediary.

Blockchain is a type of distributed ledger technology that is decentralized across a network of computers. Tokens can be issued on two types of blockchains: private permissioned blockchains and public permissionless blockchains. Private permissioned blockchains, such as Ripple, are controlled by a central entity and grant access only to select users, creating a more controlled ecosystem. On the other hand, public permissionless blockchains, like Ethereum, operate without a central authority, are more open, and offer easier access. The use of public permissionless blockchains integrates these tokens into Decentralized Finance (DeFi) protocols, such as decentralized exchanges, enhancing their utility and value. The choice of blockchain — whether a private, controlled environment or a public, open network — also determines how much control the token issuer retains over the token. Tokens on public permissionless blockchains typically offer less control to their issuers compared to those on private permissioned blockchains. Ultimately, selecting the appropriate blockchain structure aligns with the token issuer's objectives and the desired functionality of the token (Carapella, et al., 2023).

A major feature of asset tokenization lies in the facilitation of automation through smart contracts – coded programs on blockchain that execute only when predetermined conditions are met on both sides of the transaction. Smart contracts enable the automation of various financial transactions and administrative procedures, significantly reducing the need for manual intervention and intermediary services. This automation capability not only streamlines operations but also enhances security by eliminating counterparty risk, leading to more efficient and cost-effective transfer processes.

2.1. Methods of tokenization

Traditionally, when discussing real-world asset tokenization, assets have been categorized in a binary fashion, as either tokenized or not. However, as we move towards a digital asset era, it is clear that this binary classification is outdated. To describe the spectrum between a conventional and digital asset, we can use the two properties of an asset: its representation and ownership rights. The term 'representation' refers to the information outlining the asset’s economic properties, such as its functionality, underlying assets, expiration dates, and interest rates. Additionally, there needs to be a ledger, which can be either off-chain or on-chain, to verify the ownership of the asset. Off-chain assets typically have these rights and representations in a certificated (paper) form, like a bearer bond, or in a dematerialized (digital copy) form, such as an electronic stock record, both governed by legal frameworks. In contrast, on-chain assets exist in either dematerialized digitally enhanced, or digitally native forms, enforced through blockchain consensus mechanisms. It's crucial to distinguish between digitally enabled and digitally native assets, as the difference is significant yet often overlooked. Digitally enabled or digitally enhanced assets hold the title, or ownership rights, on an off-chain ledger, which itself serves as the security, and are digitally represented by a token on a blockchain. This might include, for example, a stock title that exists on an electronic ledger and is tokenized on a blockchain for added functionality. Digitally native assets, like cryptocurrency, are inherently digital and their tokens represent both their value and ownership, making the token itself the security. In other words, tokens of digitally enabled assets hold rights to claim the title on an off-chain ledger. In contrast, digitally native assets hold the right to claim the asset itself, eliminating the off-chain ledger.

Building on the understanding of different asset types and their tokenization, we now turn to the four methods of tokenization. These methods vary in the directness of the link they establish between the token and the underlying asset. We explore each method in detail, starting from the approach that offers the most direct connection between the token and the asset, to the one that provides the least direct link.

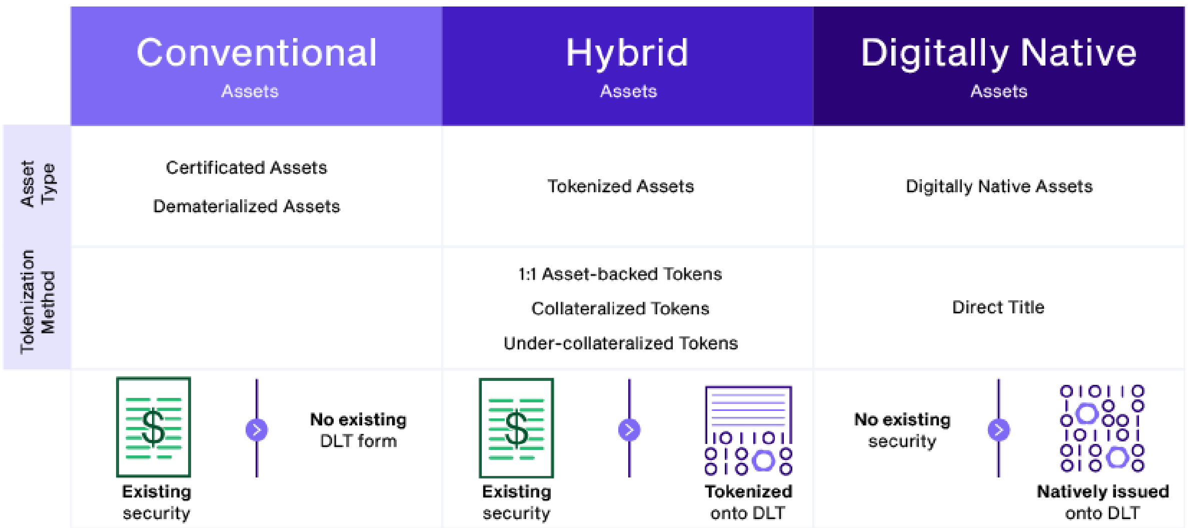
(1) **Direct title***:* In this tokenization method, the digital token serves as the record of the title, eliminating the need for custodial arrangements. This method applies only to digitally native assets (see Figure 2). A single ledger, possibly distributed, functions as the ledger for the digital tokens. For instance, when tokenizing equities, rather than issuing tokens backed by the share registry, the share registry itself could be tokenized, making the tokens the ownership records. This approach does not necessitate custodianship or dual registries, and while it can leverage a distributed ledger, it doesn't inherently require the registry to become distributed. Legal implementation for this tokenization method, however, is not currently fully available for many asset classes, and regulatory frameworks for this form of tokenization still require significant development.

(2) **1:1 asset-backed tokens***:* In this method, a custodian holds an asset and issues a token representing a claim or right to the underlying asset. This token may have the right to be swapped for the underlying asset (redemption) or the cash equivalent of the asset. An example is a financial institution issuing bond tokens against bonds it holds in a trust account, or a commercial bank issuing fiat stablecoin tokens backed by a 1:1 ratio of commercial bank money in a dedicated bank account.

(3) **Collateralized tokens:** This method involves issuing an asset token backed by assets different from the intended represented asset or associated rights. Typically, the token is over-collateralized to account for potential fluctuations in the value of the asset backing relative to the token's intended asset value. For example, Tether, a stablecoin, is backed not only by cash but also by a mix of other assets like fixed-income securities. Similarly, one could create a government bond token backed by commercial bank bonds or an equity token backed by an over-collateralized portfolio of related stocks.

(4) **Under-collateralized tokens:** This method involves issuing a token intended to track the value of an asset but is not fully collateralized. Similar to fractional reserve banking, maintaining the token value requires active management of the fractional reserve asset portfolio and open market operations. This is a riskier form of asset token, with historical instances of failures. For example, the collapsed Terra/Luna stablecoin had no independent asset backing but relied on algorithmic stabilization through supply control algorithms. Less extreme fractionally backed tokens have also been issued.

Figure 2
The Spectrum of Tokenization.
This figure shows the non-binary nature of tokenization. On one end of the spectrum are traditional off-chain assets, which exist in physical, or certificated, form or on an electronic registry (dematerialized). Most tokenized assets currently exist in a hybrid model, where tokens are transferred on-chain, but they represent a right to ownership held on a traditional off-chain ledger. Hence, these assets are termed *tokenized securities* and are usually: (1) one-to-one asset-backed tokens, (2) collateralized tokens, and (3) under-collateralized tokens. On the other end of the spectrum are *digitally native* assets, which themselves are the ownership rights.



2.2. Potential gains from tokenization

The efficiency gains associated with the tokenization of real-world assets primarily stem from the utilization of distributed ledger technology (DLT). This underlying technology facilitates transparency, enables automation and operational cost savings, and eliminates intermediaries and transaction counterparty risk. These advantages, in comparison to the existing financial system, contribute to faster settlement speeds and cost savings through simpler yet more flexible financial market infrastructure (Nassr, 2020).

Atomic settlement. The integration of distributed ledger technology and tokenized assets introduces the concept of atomic settlement. Presently, settlements are orchestrated through central counterparties, and the prevalent security settlement approach is a rolling cycle. In this approach, despite a trade being executed on a specific day, the actual settlement—transferring ownership based on a predetermined agreement—typically occurs one to three days later. This involves two legs or transfers: the delivery leg, transferring ownership from the seller to the buyer of the security, and the payment leg, transferring cash from the buyer to the seller (Bech, Hancock, Rice, and Wadsworth, 2020). Atomic settlement, facilitated by smart contracts, involves programmable code that simultaneously executes either both legs of the transaction or neither if pre-specified conditions are not met. Consequently, atomic settlement eradicates counterparty risk, while significantly boosting transaction speed and efficiency. Furthermore, leveraging smart contracts for trade settlement eliminates the need for collateral margin requirements, as there is no risk of failed delivery and the subsequent trade reconciliation. This, in turn, releases the capital tied up in margin requirements, indirectly contributing to heightened liquidity in the financial markets (Nassr, 2020).

Increased liquidity. The transition to tokenized assets significantly enhances the ease of transferring titles between individuals, transforming previously non-tradable assets into tradable ones. For example, in current financial markets, it is impossible to trade individual real estate assets mainly due to high transaction costs, lengthy and complex legal and regulatory processes, and the illiquid nature of real estate as an asset class. These factors make it challenging to quickly buy or sell individual properties on a public exchange, unlike more liquid assets such as stocks or bonds. Additionally, the unique characteristics of each property, such as location, condition, and legal status, complicate the standardization required for public trading. Through tokenization, the trading of individual real estate assets becomes viable. Smart contracts streamline the process by removing numerous intermediaries, facilitating straightforward title transfers, and ensuring compliance checks, all of which lead to a substantial reduction in transaction costs. The same applies to other currently illiquid assets such as art and collectibles, infrastructure projects, or private equity stakes.

Tokenization of assets also increases liquidity by enabling new distributed markets such as automated market makers. They facilitate constant liquidity by autonomously pairing buyers and sellers within an asset pool, maintained by liquidity providers through smart contracts on the blockchain. Since smart contracts are programs that can be run continuously, the liquidity is provided on demand 24/7, unlike the traditional market system which operates within set trading hours. According to arguments presented by Sazandrishvili (2020), Nassr (2020), and Carapella et al. (2023), liquidity would also be further facilitated through fractional ownership opportunities, reduced minimum investment requirements, diminished entry barriers, and simplified asset trading.

Reduction in intermediation. The decentralized data structure presents an opportunity to replace traditional middlemen responsible for data verification with smart contracts seamlessly integrated into the blockchain. Additionally, there is potential for smart contracts to replace another financial intermediary, the Central Securities Depository. This substitution would involve automating various processes, including asset ownership transfers, dividend disbursements, and interest payments (Auer, 2019).

Enabling automation. A major advantage of asset tokenization lies in the facilitation of automation through smart contracts — coded programs on the blockchain that execute only when predetermined conditions are met. Smart contracts can streamline many manual tasks within sectors like insurance, exemplified by automating policy issuance and claims payouts. For instance, in the event of a flight delay or cancellation, a smart contract could trigger an automatic payout under travel insurance, eliminating the need for manual claim processing.

The efficacy of such automation, however, largely depends on the integration and real-time monitoring of relevant data. Third-party services that provide smart contracts with external data are called oracles. Oracles act as a bridge between the blockchain and the outside world because smart contracts, by design, cannot access or interact with external data. Hence, automation is more likely to happen in asset classes where data can be quantified, standardized, and easily accessible by oracles reliably and securely. Asset classes such as equities, bonds, and derivatives are prime examples, where market data is readily available and can be efficiently integrated into smart contracts. Conversely, sectors, where data is subjective, difficult to quantify, or not readily accessible, pose significant challenges. Real estate, for instance, involves complex transactions that often require manual verification of legal documents, subjective property evaluations, and compliance with diverse regulatory frameworks, making full automation through smart contracts more challenging.

Facilitating compliance. Another important aspect of tokenized assets is compliance. The development of know-your-customer (KYC), anti-money laundering (AML), and terrorism financing regulatory frameworks has been a particularly important aspect of creating a safe environment in terms of digital finance and transactions. The properties of tokenized assets provide an appropriate environment for easier and more uniform compliance with all the criteria due to the underlying technology, allowing the regulations to become more standardized and factorized. The KYC and AML regulations could potentially be encoded either on the blockchain or the individual asset's transfer rules, allowing for more direct and efficient interactions (Laurent et al., 2018). For instance, every time a customer starts a relationship with a new financial institution, the underlying information about the customer's identity can be automatically transferred to the financial institution with the consent of the customer.

Treat et al. (2017) explore the effects of tokenization on banks' infrastructure costs. They map more than 50 operational cost metrics and assign the magnitude of efficiency gains from tokenization for each of them. They find that 30% to 50% of total compliance costs could be saved through improved auditability and transparency of financial transactions.

Automated market makers. Smart contracts also have the potential to replace traditional market makers, transforming the existing system. Conventional market makers, acting as liquidity providers, engage in the market by playing the role of both buyer and seller of securities, ensuring constant tradability and liquidity. In contrast, smart contracts pave the way for a novel market type known as automated market maker (AMM). AMMs offer continuous liquidity by automatically matching buyers and sellers within a pool of assets provided by liquidity providers. This pool, controlled by a smart contract embedded in the blockchain, algorithmically determines asset prices (Foley et al., 2023). The automation inherent in AMMs results in cost-cutting and performance-enhancing features. Foley et al. (2023) find that transaction costs associated with AMMs are significantly lower than those currently present in the system, especially for low-volatility and high-volume assets, as well as medium-volatility and high-volume assets.

2.3. Risks and costs of RWA tokenization

Whilst there are numerous impactful benefits, the adoption of tokenized assets does not come without concerns. The risks concerning the adoption of tokenized real-world assets are mainly based on the underlying technology as well as the regulatory issues. The most common concerns include cyber risks, scalability of the system, the settlement process, stability, and efficiency of the network on the technical side of the spectrum. Regulatory aspects such as anti-money laundering risks, governance risks, identity, data protection, and privacy risks are another concern (Nassr, 2020). Auer (2019) argues that tackling the issues related to digital asset regulations requires avoiding trying to fit new and innovative assets and technologies into the existing regulatory models but rather exploring the possibilities of using blockchain technology and smart contracts to improve the ease of compliance with regulatory requirements.

In addition to technological and regulatory hurdles, investor uncertainty and behavior add another layer of complexity to the adoption of tokenized assets. To achieve widespread acceptance, there's a need for significant efforts in educating and raising awareness about this major shift. Furthermore, once adoption takes place, speculative trading could cause some assets to become overvalued. The digital nature of these assets might also lead to increased volatility, impacting price stability. Additionally, environmental concerns arise from the high energy consumption required by some blockchain consensus mechanisms. These challenges highlight the diverse issues that need to be addressed to realize the benefits of tokenization in the financial world fully.

Transitioning to a tokenized financial system would also incur significant costs. Infrastructural changes required to support blockchain and tokenization technologies represent the most significant costs. These include investments in secure, scalable blockchain platforms, the development or acquisition of compatible software for managing tokenized assets, and training for staff to navigate the complexities of these new systems effectively. Additionally, there's the cost of integrating these systems with the existing financial infrastructures, ensuring seamless interoperability while maintaining the security and integrity of transactions. Beyond these, educational changes required to overcome skepticism and build a solid understanding of tokenization processes would also constitute substantial both direct and opportunity costs for the government. Lastly, the electricity consumption associated with running energy-intensive blockchain consensus mechanisms poses not only a financial challenge but also raises concerns regarding environmental sustainability.

2.4. Current state of RWA tokenization

Despite being in its nascent stages, RWA tokenization has demonstrated significant growth in recent years. Although the available statistics may only reflect a conservative estimate of the value of tokenized assets and projects underway, they nonetheless illustrate a noteworthy trend of development within the given period. By the end of 2020, the aggregate value of tokenized private credit was reported at $9 million, a figure that saw a more than fifty-fold increase by the end of 2023, reaching $485 million.[3] Similarly, tokenized US treasuries increased from $105 million to $718 million in 2023 alone. Presently, the market is predominantly comprised of fiat-collateralized stablecoins, which constitute more than 90% of the total market share of tokenized assets; during the past four years, the market capitalization of stablecoins has grown from $4 billion to $136 billion.

The tokenization industry is still in its early stages. Despite this, there has been significant interest from key players in the financial sector. For instance, in 2023, Siemens issued a $64 million bond on the Polygon blockchain, the European Central Bank began investigating wholesale Central Bank Digital Currencies, and Mastercard launched a pilot project to explore tokenized bank deposits.[4] Similarly, HSBC started trading gold tokens, Nasdaq developed a smart contract to facilitate the trading of carbon credits, and Goldman Sachs launched their digital asset platform GS DAP with the issuance of a $100 million digital bond for the European Investment Bank.[5]

A major hurdle to widespread tokenization is regulatory uncertainty. Only a handful of countries have specific regulations for asset tokenization. For example, Switzerland recognizes digital assets as bearer assets, while France employs the CAST framework, a hybrid model combining an off-chain register with blockchain for settlement. The EU, US, UK, Singapore, and Japan are among those making regulatory progress, contrasting with countries like India, which lacks regulation, and South Korea and China, where Initial Coin Offerings and token offerings are banned. This regulatory disparity poses challenges to the global scaling of tokenization.

---

[3] Data on the current state of tokenization, including historical market capitalization of tokenized private credit, US treasuries, and stablecoins is from the RWA.xyz website section “Dashboard.”

[4] Latest major tokenization and decentralized finance projects are reviewed in Binance Research’s July 2023 report “Real-World Assets: State of the Market.”

[5] A comprehensive look at the RWA tokenization industry with data and insights is available in The Tokenized Asset Coalition’s January 2024 report “The State of Asset Asset Tokenization: 2024 Outlook.”

The Markets in Crypto-Assets (MiCA) regulation, adopted by the European Union in 2023, addresses the challenge of the regulatory disparity, aiming for a harmonized approach to asset tokenization. MiCA represents one of the most advanced pieces of legislation on crypto assets globally, defining them as “digital representations of value or rights which may be transferred and stored electronically using distributed ledger technology or similar technology.”[6] Similarly, another important development has been the European Blockchain Regulatory Sandbox, an initiative launched by the European Commission designed to foster innovation within the blockchain technology sector across Europe. Running from 2023 to 2026, this sandbox aims to provide a controlled environment where companies can test their blockchain-based products and services while engaging in dialogue with relevant regulators. It enables both regulators and innovators to enhance their understanding of cutting-edge blockchain technologies.

3. Methodology

We evaluate each asset class individually to quantify the economic benefits of RWA tokenization. While the benefits are broadly applicable, their impact can differ significantly between asset classes. For example, tokenizing already efficient asset classes like equities may not yield as large gains as tokenizing less efficient classes, such as over-the-counter (OTC) derivatives or foreign exchange (FX) payments.

We introduce Equation 1 to calculate the economic value added (EVA) of tokenizing a specific asset class, denoted as *i*:

$$EVA_i = V_i \times G_i \times F_i \tag{1}$$

In this equation, variable V_i denotes the market capitalization of the asset class i, G_i denotes the efficiency gains per dollar tokenized and F_i denotes the fraction of the asset class that could realistically be tokenized by 2030. We first present the market capitalization of all the asset classes in our analysis. We then calculate the efficiency gains from tokenization for these asset classes and normalize them against the market capitalization of the corresponding asset class, yielding a metric of efficiency gains per dollar tokenized (G_i). We multiply this

[6] EU regulations on tokenization are reviewed in The Tokenizer’s February 19, 2024, report “Regulation at a Glance – Europe.”

figure by the total market size of the asset class (V_i) to estimate the total potential efficiency gains if the asset class was fully tokenized Lastly, we scale these results down according to our analysis of the tokenizable fraction (F_i), or what proportion of the asset class could realistically be tokenized by 2030. In our calculations, we deliberately exclude the cost side of tokenization to determine the peak magnitude of potential gross gains.

Equation 2 aggregates the economic benefits across all asset classes to calculate the total economic value-add of tokenization:

$$EVA_{TOTAL} = \sum_i EVA_i \tag{2}$$

We compile data to estimate the total market size of real-world assets, detailed in Table 1. In total, the RWA market size is approximately $1,040 trillion where the largest five asset classes are real estate ($380 trillion), private debt ($146 trillion), commodities ($128 trillion), and public equity ($109 trillion). This table provides the market size of real-world assets (V_i) input to equation (1). In the next two sections, we separately estimate G_i, and F_i variables for major asset classes, before combining them to obtain EVA_i and EVA_{TOTAL}.

4. Estimating economic gains per dollar tokenized (G_i)

In this section, we estimate the annual economic gains per $1 of assets tokenized. We focus on analyzing four asset classes in depth: real estate, public equity, public debt, and foreign exchange, attaining the corresponding G_i values for those asset classes. From those asset classes, we extrapolate the estimates of G_i for other asset classes.

We focus on these specific asset classes for the in-depth analysis for two main reasons (noting it is infeasible to separately analyze each asset class). First, they are among the largest asset classes and therefore are likely, through sheer size, to account for much of the total economic potential from tokenization. Estimating their G_i variable accurately is therefore important. Second, the amount of available data is significantly higher for these asset classes, allowing us to make more accurate G_i estimates. Hence, these asset classes serve as useful benchmarks from which to extrapolate our findings to additional asset classes. The xtrapolation draws on data from the International Securities Services Association report "DLT in The Real World 2022."[7]

Table 1
The global market size of real-world assets (V_i).

This table reports the estimated market capitalization in descending order for ten real-world asset classes: (1) real estate, (2) private debt, (3) commodities, (4) public equities, (5) public debt, (6) foreign exchange, (7) investment funds, (8) over-the-counter (OTC) derivatives, (9) private equity, and (10) carbon credits. The table includes the asset class rank (*n*), name (*Asset Class*), market size in USD trillions (*Market size*), percentage of total RWA market size (*% of Total*), where available, the average daily trading volume in USD billions (*ADV*), and the source of the values (*Source*). The first source corresponds to the value of *Market size*, and the second source to the *ADV* variable.

n	Asset Class	Market size ($Tn)	% of Total	ADV ($Bn)	Source
1	Real estate	379.7	36.5%	2.6	Savills "Total Value of Global Real Estate: Property remains the world's biggest store of wealth"; McKinsey & Company "McKinsey Global Private Markets Review 2024."
2	Private debt	145.7	14.0%	-	International Monetary Fund "Global Debt Monitor 2023."
3	Commodities	128.3	12.3%	162.6[8]	Statista data "Commodities — Worldwide"; Statista data "Financial assets by daily trading volume 2023."
4	Public equities	109	10.5%	721	Securities Industry and Financial Markets Authority "Quarterly Report: US Equity & Related, 4Q23"; Blackrock "Global ETF Market Facts: three things to know from Q3 2023."
5	Public debt	92.4	8.9%	-	International Monetary Fund "Global Debt Monitor 2023."
6	Foreign exchange	87.2	8.4%	2,107	Trading Economics data "Money Supply M2"; Bank for International Settlements "OTC foreign exchange turnover in April 2022."
7	Investment funds	63.1	6.1%	-	Investment Company Institute "Investment Company Fact Book 2021."
8	OTC derivatives	20.7[9]	2.0%	10,626	Bank for International Settlements "OTC derivatives statistics at end-December 2022"; Bank for International Settlements "OTC interest rate derivatives turnover in April 2022."
9	Private equity	11.7	1.1%	1.2	McKinsey & Company "McKinsey Global Private Markets Review 2024"; Reuters "Recession risk, rate rises drive down private equity deal volumes to 4-year low.."

[7] The ISSA report provides data from industry experts about the relative benefits of tokenization for different asset classes.
[8] Indicates the average daily trading volume (ADV) of gold.
[9] Market size of OTC derivatives is indicated as the market value of contract positions ($20.7 trillion) rather than notional value ($600 trillion), since in most cases the notional is never exchanged.

10	Carbon credit	1.9	0.2%	3.8	Swinkels, 2023, “Trading Carbon Credit Tokens on the Blockchain”; Reuters “Global carbon markets value hit record $949 bln last year — LSEG.”
	Total	1,039.7			

For each asset class, we estimate the G_i as the sum of a range of different components specific to that asset class, as described in the following subsections. For some components, we can draw on estimates from existing studies, whereas for others we require source data and estimate the components ourselves. Given the innovative and exploratory nature of this research, it is essential to establish from the outset the unique challenges posed by estimating the economic value of an emerging phenomenon that has yet to manifest on a significant scale. This situation inherently limits the availability of historical data, necessitating reliance on a greater number of assumptions and rough approximations than typically employed in analyses of established phenomena. The primary goal of these forward-looking estimates is not to pinpoint precise values but to approximate the potential scale of economic impact.

4.1. Foreign exchange

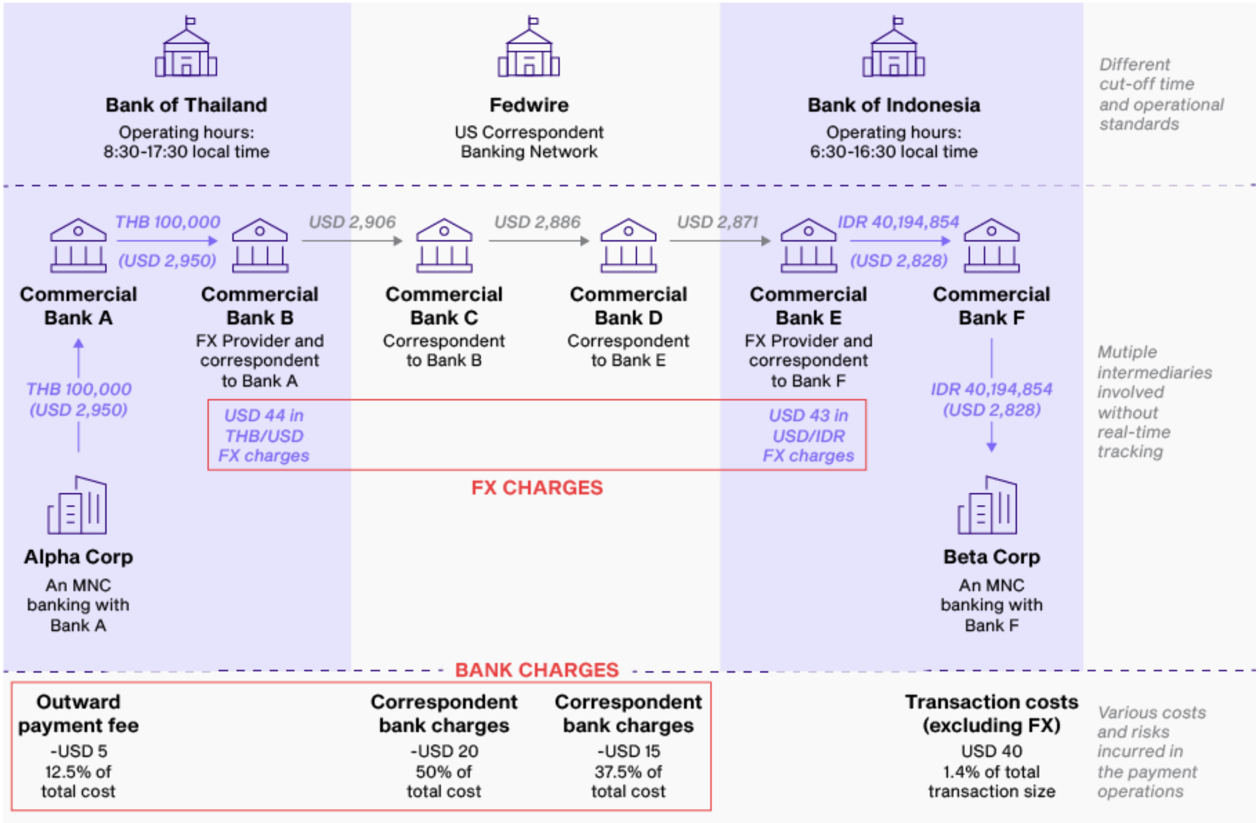
4.1.1. Reduced transaction costs

The first potential cost saving from tokenizing fiat currencies, either as central bank digital currencies (CBDCs) or stablecoins (cryptocurrencies pegged to a specific asset or a pool of assets, designed to maintain stable value) and using them for cross-border fiat currency transactions, is reduced transaction costs. Transaction costs consist of two components: bank fees from facilitating cross-border payments and FX costs, arising from bid-ask spread during currency conversion.

Reduced correspondent bank charges. The existing procedures for cross-border payments suffer from cost inefficiencies, are slow, and lack transparency. It is not uncommon for an FX transaction to involve five or more intermediaries, each imposing substantial fees (see Figure 3, Panel A). Moreover, the initiator of the transaction lacks visibility into the payment status, resulting in a lack of control and transparency. This, in turn, exposes the transacting party and the banks upstream to significant settlement risk if any of the downstream banks fail to fulfill their obligations.

Multi-currency central bank digital currency (mCBDC) is a multilateral corridor that serves as a shared exchange place for participants in multiple jurisdictions to conduct cross-border payments via multiple currencies in the form of CBDCs (see Figure 3, Panel B). The "multi-currency" aspect implies that these digital currencies can seamlessly interact and be exchanged across different countries and financial systems. The key benefit of mCBDCs lies in their ability to facilitate more efficient, secure, and faster cross-border transactions through atomic settlement. By leveraging this technology, the need for intermediaries traditionally involved in foreign exchange and international payments can be significantly reduced.

Panel A: Cross-border payment flow via correspondent banking.



Panel B: Smart contract-based liquidity provisioning and market making.

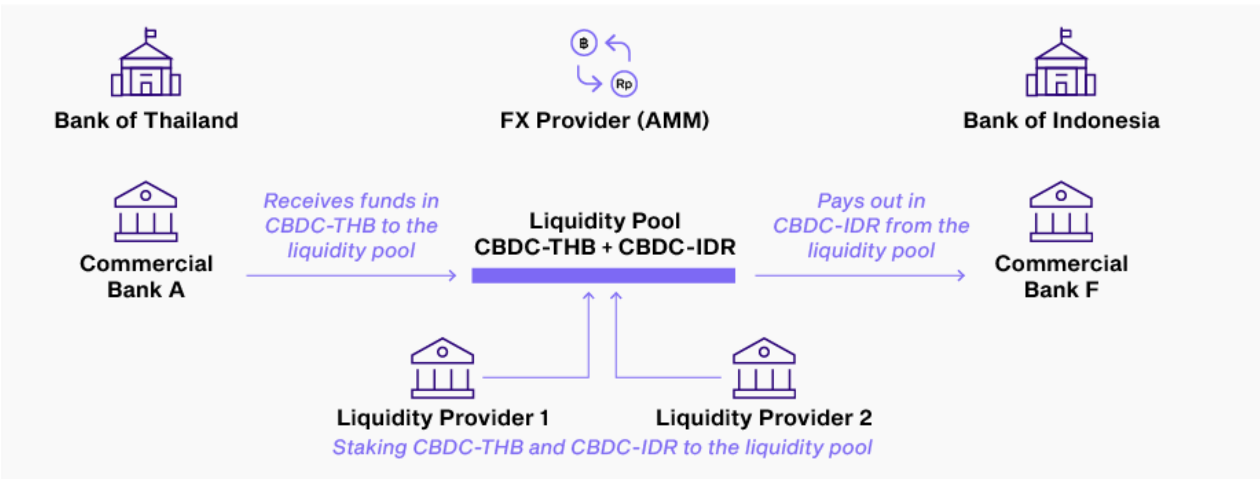


Figure 3
How tokenization changes the process of cross-border payments

This figure illustrates cross-border payments via the current system (Panel A) and automated market makers (Panel B). In Panel A, cross-border payment flow via correspondent banks (current system), with two major costs: (i) multiple bank charges and (ii) FX conversion costs. In Panel B, cross-border payment flow via automated market maker using CBDCs, where a liquidity pool replaces the 4 correspondent banks.

According to Ekberg et al. (2021), corporations move around approximately $23.5 trillion in cross-border payments, with bank charges constituting approximately 0.5%, or $120 billion, annually. This is because cross-border payments frequently involve 2 to 6 intermediary bank charges to reach the recipient due to the complexity of the financial network. The study looks at how these costs could be reduced using multi-currency central bank digital currency (mCBDC), a digital form of fiat currency issued by central banks, designed to facilitate cross-border payments. Unlike traditional CBDCs which are typically limited to a single country's currency, mCBDCs encompass multiple currencies within a unified digital framework. By enabling direct transactions between the payer and the payee across borders, Ekberg et al. (2021) assume that at most one corresponding bank to continue facilitating cross-border payments. Using multiple models, the study suggests a reduction in bank fees from $27 to $5 when 2 correspondent banks are involved, implying an 81% reduction. Consequently, they estimate that approximately 80% of bank fees, or **$100 billion** per annum, could be saved globally through the implementation of a full-scale mCBDC network.

<u>Reduced FX costs.</u> Another part of total transaction costs is the FX costs incurred from the bid-ask spread. To calculate the potential cost savings, we refer to research by Foley et al. (2023). They compare the trading costs of traditional trading mechanisms versus automated market makers (AMMs). They analyze 39 million AMM transactions and derive a model of liquidity equilibrium. The study suggests that AMMs can potentially reduce trading costs for multiple asset classes, including FX. Foley et al. (2023) estimate that the use of AMMs could decrease the FX costs (mean bid-ask spread) by 66% for major currency pairs and by 64% for exotic currency pairs.[10]

To calculate the total annual savings for the FX market, we first extract average daily volume (ADV) data from BIS (2022) Triannual survey of seven major and 14 exotic currency pairs with the highest ADV. For the chosen currency pairs, we then retrieve year-to-date bid-ask quotes from Refinitiv Eikon Datastream. Subsequently, we calculate the midquote, the

[10] Major currency pairs include pairs with USD on one side and one of the eight major currencies on the other side. Major currencies are the US dollar, euro, Japanese yen, British pound, Canadian dollar, Australian dollar, Swiss franc, and New Zealand dollar. Similarly to the study by Foley et al. (2024), we define exotic currency pairs as all the other besides the major ones.

spread, and the relative spread (spread over midquote) for each currency pair in the sample period. We then take the average relative spread for each pair over the sample period and multiply it with the ADV to compute the daily transaction cost. To calculate the new average relative spread, we reduce the initial relative spread of major and exotic currency pairs by 66% and 64%, respectively. We then determine the new daily transaction cost by multiplying the new average relative spread with the ADV of each currency pair. We can then calculate the daily cost savings for each pair by subtracting the new daily transaction cost from the initial one.

Table 2
Daily FX cost savings.

This table reports the daily cost savings for three major currency pairs (USD/EUR, USD/JPY, and USD/GBP), and for three exotic currency pairs (EUR/GBP, EUR/JPY & EUR/CHF). The measures for each currency pair include average bid-ask spread relative to the average midquote in basis points (*Average RS*), average daily volume in USD billions (*ADV*), daily transaction cost in USD millions (*DTC*), new relative spread after reduction of FX costs in basis points (*New RS*), new daily transaction costs in USD millions after the reduction of FX costs (*New DTC*), and daily cost savings in USD millions (*Savings*). Calculations based on data from the Bank for International Settlements report "OTC foreign exchange turnover in April 2022."

Currency pair	Average RS (bps)	ADV ($Bn)	DTC ($Mil)	New RS (bps)	New DTC ($Mil)	Savings ($Mil)
USD/EUR	2.55	1,706	434.38	1.97	147.69	97.74
USD/JPY	1.89	1,014	191.24	1.46	65.02	43.03
USD/GBP	2.99	714	213.19	1.02	72.48	140.70
EUR/GBP	6.28	154	96.70	2.26	34.81	61.89
EUR/JPY	4.87	103	50.18	1.75	18.07	32.12
EUR/CHF	6.10	68	41.46	2.10	14.93	26.54

To extrapolate the total annual savings from the sample, we perform additional calculations. We divide daily cost savings over ADV for each currency pair and take the ADV-weighted average of them for major and exotic currency pairs separately, to get the relative benefit for each category. By multiplying this value by a thousand, we get the average savings per thousand dollars traded. We then compute the ADV for both groups; for major currency pairs, the total ADV equals the sample ADV ($4.6 trillion), since we have a full sample. As we know the total ADV of the FX market ($7.5 trillion) from the BIS (2022) report, we can easily calculate the ADV for exotic currency pairs by subtracting the ADV of major currency pairs, resulting in $2.9 trillion.

Finally, we multiply the ADV of both groups with the respective savings per thousand dollars traded, giving us the total daily savings. We then multiply the daily savings by 252 trading days and arrive at total annual savings of $207.9 billion for major pairs and $387.9 billion for exotic pairs. By combining these savings, we estimate that AMMs can potentially reduce global FX costs by **$595.8 billion** annually.

Table 3
Total annual FX cost savings.

This table reports the total annual cost savings for major and exotic currency pairs. Measures for the currency categories include average cost savings per thousand dollars traded (*Savings per Thousand Dollars Traded)*, average daily volume in USD billions (*ADV*), total daily cost savings in USD billions (*Total Daily Savings*), and total annual cost savings in USD billions (*Total Annual Savings*). Calculations based on data from the Bank for International Settlements report "OTC foreign exchange turnover in April 2022."

	Major Currency Pairs	Exotic Currency Pairs
Savings per Thousand Dollars Traded ($)	0.18	0.53
ADV ($Bn)	4,617	2,891
Total Daily Savings ($Bn)	0.83	1.54
Total Annual Savings ($Bn)	207.9	387.9

4.1.2. Reduced settlement failures

Millions of FX transactions happen between brokers and dealers daily with most of the trades being only partly funded, leading to a high risk of failure-to-deliver (FTD) events. Additionally, FTD events often occur not only between the transacting parties but also within correspondent banks due to errors or lack of funds, further delaying settlements. Atomic settlement, enabled through tokenization, requires that the transaction is fully funded by both sides by simultaneously exchanging both assets, eliminating the risk of a failed settlement.

Glowka and Nilsson (2022) report that nearly one-third of daily FX turnover, totaling $2.2 trillion, lacks risk mitigation measures. Around 10% of FX trades do not settle as planned; extracting this value to the part of trades without risk mitigation measures, we assume a 10% failure rate for these unprotected settlements.[11] This translates to a daily exposure of $220 billion. The penalty rate of a failed FX settlement differs by country; in the EU the penalty would be 0.5 basis points per day[12] whereas in Australia it would be 10 basis points,[13] or 0.1%. Assuming an average penalty rate of 5 basis points globally, the estimated fines for failed settlements would amount to **$27.7 billion** annually ($220 billion × 0.05% × 252 days).

[11] Swift's January 2024 article "Fewer settlement fails through more visibility" states that around one in 10 trades does not settle as expected, while one in 20 trades settles late.

[12] Euroclear December 2019 report, "CSDR Settlement Discipline Guide," indicates daily penalty rates for late settlement of financial instruments equal to 0.5 basis points per day.

[13] ASX Clearing & Settlement January 2024 report, "Schedule of Fees," states that the penalty rate for settlement failure equals 10 basis points per day.

Global settlement fail rate of 2% leads to hidden costs of approximately $3 billion per annum.[14] These might include staff costs, regulatory capital, cash liquidity, inventory shortages, and other indirect costs that are incurred during a settlement process. The report estimates that while the total cost of a successful trade is approximately $0.37, the cost of a failed trade might be 100 to 1000 times larger. We assume equal allocation of these costs to different financial asset classes. Hence, we calculate the proportion of market capitalization of FX to other financial assets, which equals 13%.[15] Thus, we approximate that global FX settlement failures lead to hidden costs of **$390 million** ($3 billion × 13%) per annum.

4.1.3. Reduced clearinghouse costs

Reduced clearing and settlement operational costs. While centralized clearing reduces the occurrences and costs of settlement failures, it also introduces additional operational expenses that market participants absorb. To determine these costs, which would potentially be eliminated or significantly reduced through atomic settlement (as explained in the Literature Review section), we retrieve the amount of revenues earned by clearinghouses from clearing and settlement activities in FX.

We assess the saved costs in clearing and settlement by examining the annual reports of the seven largest clearinghouses, namely LCH, Euroclear, ICE Clear, Cboe Clear Europe, CME Group, Depository Trust and Clearing Corporation (DTCC), and Options Clearing Corporation (OCC). The clearing and settlement revenue extracted from these clearinghouses' latest available annual reports totals approximately $15.8 billion (see Table 4). Based on the high concentration of the clearing and settlement market, in our analysis, we conservatively assume that the revenues of these 8 major clearinghouses fully constitute the total clearing and settlement market. The FX segment generally constitutes around 5% of the total clearing revenue, amounting to potential efficiency gains of **$790 million** per annum.[16]

---

[14] Depository Trust & Clearing Corporation 2020 infographic "Hidden Impact: The Real Cost of Trade Fails" estimates costs and losses from just a 2% global fail rate to be approximately $3 billion annually.

[15] Calculated as the proportion of the FX asset class ($87 trillion) to all financial asset classes ($660 trillion). Financial asset classes include all the asset classes considered in our research, excluding real estate (see Table 1).

[16] CME Group report "CME Group Annual Report 2022" states that FX clearing and settlement revenue constituted 4.5% of their total revenue in 2022.

Table 4
Clearing and settlement revenue of central counterparties.

This table reports the total clearing and settlement revenue in descending order for eight major clearinghouses: (1) ICE Clear, (2) CME Group, (3) Cboe Clear Europe, (4) Depository Trust & Clearing Corporation [DTCC], (5) London Clearing House [LCH], (6) Euroclear, (7) Australian Securities Exchange (ASX), and (8) Options Clearing Corporation [OCC]. The table includes the clearinghouse rank (*n*), name (*Clearinghouse*), revenue from clearing and settlement in USD millions (*Revenue*), and the source of the values (*Source*).

n	Clearinghouse	Revenue ($Mil)	Source
1	ICE Clear	5,023	Intercontinental Exchange “Annual report 2022.”
2	CME Group	4,143	CME Group “CME Group Annual Report 2022.”
3	Cboe Clear Europe	2,939	Cboe Global Markets “Annual Report 2022.”
4	DTCC	1,376	Depository Trust & Clearing Corporation “2022 DTCC Annual Report.”
5	LCH	758	LCH “LCH Group Holdings Limited Financial Statements 2022.”
6	Euroclear	707	Euroclear “Euroclear Holding Consolidated Financial Statements 2022.”
7	ASX	409	ASX “ASX Annual Report 2023.”
8	OCC	404	OCC “OCC 2022 Financials.”
	Total	15,759	

Reduced capital inefficiency costs. Aside from the clearing and settlement costs, market participants presently maintain substantial amounts of capital tied up in central counterparties as collateral to mitigate the risks and consequences of failed settlements. In contrast to atomic settlement, where capital is utilized to pre-fund the trade itself, the current system requires additional funds, intensifying the capital requirements for market participants.

To quantify the benefits of releasing this collateral, we can consider the opportunity cost of capital. In the third quarter of 2023, central counterparties globally held $1.8 trillion in collateral, of which $1.66 trillion were initial margins and $0.17 trillion were default funds.[17] Following the same assumption as earlier, we allocate 5%, or $90 billion, to the FX market segment. Using the US Effective Federal Funds Rate (EFFR) of 5.5% as the opportunity cost of capital, we estimate that the annual capital inefficiency cost for the FX market is approximately **$4.5 billion**.[18]

[17] Data on the collateral of central counterparties obtained from the Global Association of Central Counterparties report “Public Quantitative Disclosure 2023Q3.”

[18] Effective Federal Funds Rate (EFFR) is available on the Federal Reserve Bank of New York “Markets & Policy Implementation” page under the section “Data.”

4.1.4. Reduced middle- and back-office costs

We can estimate the middle- and back-office costs that are passed on to market participants and could potentially be reduced through tokenization. Middle- and back-office involves processes such as clearing and settlement, trade support, collateral management, client reporting, and risk management, among many others. It is especially prominent in markets that are less structured and automated, like over-the-counter (OTC) markets, which encompass money markets and fixed-income markets. Although tokenization will not completely remove these middle- and back-office expenses, it can significantly reduce them.

To quantify the costs, we base our calculations on two key data points: the proportion of staff costs in total operating expenses for the world's 35 largest banks, and the overall operational expenses in the global banking industry. In 2021, staff costs accounted for 53.6% of the total operational costs for major banks.[19] This figure provides a reasonable estimate for the global ratio of personnel to total operational costs, considering that for most banks, staff expenses make up more than half of their total costs. This implies an estimated annual global personnel expense of $1.74 trillion.[20]

Historical data of J. P. Morgan's full-time employees show an average middle- and back-office to front-office worker ratio of 2 to 1.[21] Consequently, we estimate that two-thirds, or $1.16 trillion, of the total global personnel expense is attributable to middle- and back-office costs. As reported by Treat et al. (2017), capital market infrastructures utilizing DLT can achieve cost reductions of around 50% in business operations compared to traditional systems not employing DLT. Hence, up to $580 billion of annual middle- and back-office costs could potentially be saved globally. We look at the market sizes of real-world asset classes (see Table 1) to estimate how much of that is attributable to the FX segment. The proportion of FX market capitalization to total RWA market size excluding real estate equals 13%[15]. We exclude real estate and other physical assets from this calculation, considering that the market structure and trading processes of physical assets is significantly different from financial assets. Using this

---

[19] Global Data September 19, 2022, article "Employee costs account for over half of total operating expenses of global banks in 2021, says GlobalData" estimates that employee costs account for more than 50% of the total operating costs of leading global banks in 2021.

[20] Assuming global banking operating costs of $3.25 trillion, as indicated in the FinModelsLab April 17, 2023, article "The Costs of Running a Commercial Bank: Understanding Operational Expenses."

[21] Insights into J.P. Morgan's workforce statistics are reviewed in Business Insider's January 6, 2016, article "One anecdote sums up how Wall Street's workforce has changed since the financial crisis."

estimate, we can calculate the potential middle- and back-office cost savings for the FX segment, which equal **$75.4 billion** ($580 billion × 13%) per annum.

4.1.5. Reduced compliance costs

Tokenization can greatly reduce both the administrative burden and the costs associated with compliance by automating verification processes, increasing transparency, and enhancing the auditability of trades. For instance, before approving a transfer, the smart contract can perform checks to ensure all requirements are fulfilled and verify the necessary confirmations associated with the identities of the buyer and seller. Because this process is implemented on-chain using smart contracts, it can efficiently and cost-effectively handle even highly complex compliance requirements. Moreover, the immutability of blockchain technology prevents unauthorized changes or tampering, thereby boosting the accuracy and reliability of regulatory reporting, audits, and investigations.

In 2022, global financial crime compliance expenditures reached $206 billion.[22] Treat et al. (2017) suggest that enhancing transparency and auditability could reduce compliance costs by 30% to 50%, translating into annual savings of $61.8 billion to $103 billion. Extending this analysis to the foreign exchange market, which represents 13% of the financial assets market size, the potential compliance cost savings for FX could range from **$8 billion** to **$13.4 billion** each year.

Table 5
Efficiency gains for FX asset class.

This table reports the total efficiency gains by category of economic impact for the FX asset class globally. The table includes the category of economic impact (*Category of Economic* Impact), the estimated efficiency gains in USD billions per annum (*Efficiency Gains*), and the implied savings per dollar tokenized in basis points (G_i) relative to the market size of the FX asset class.

Category of Economic Impact	Efficiency Gains ($Bn p.a.)	G_i (bps)
Reduced correspondent bank charges	$100.0	
Reduced FX costs	$595.8	
Reduced penalties for settlement failures	$27.7	
Reduced hidden costs of settlement failures	$0.4	
Reduced operational costs of clearing & settlement	$0.8	
Reduced capital inefficiency costs	$4.5	
Reduced middle- and back-office costs	$75.4	
Reduced compliance costs	8.0	
Total	$812.6	93.2

[22] LexisNexis Risk Solutions September 2023 report "True Cost Of Financial Crime Compliance Study, 2023" estimates financial crime compliance costs amounting to $206 billion.

4.2. Public debt

4.2.1. Reduced settlement failures

The average value of failed US Treasury bond settlements equals \$32.5 billion per day while agency debt securities amount to average failed settlements of \$377 million per day.[23] Fixed Income Clearing Corporation (FICC) charges an annual rate of 3% minus the Target Fed funds rate on the value of the failed settlements of Treasury and agency debt securities (Garbade, Keane, Logan, Stokes, and Wolgemuth, 2010). Considering a long-term average Target Fed Funds rate of 2.5%, the FICC charge would be 0.5% on both types of debt securities and equal around \$164 million per annum (\$32.5 billion × 0.5% + \$377 million × 0.5%).

Data from the European Securities and Markets Authority (ESMA, 2023) shows that the one-year moving average of settlement failures in the EU Central Security Depositories (CSDs) averaged 3% for corporate bonds and 4% for government bonds at the end of 2022. The total notional traded volume of EU sovereign issues amounted to €25.3 trillion, or \$27.1 trillion, in 2022.[24] Consequently, the average value of failed settlements for government bonds in 2022 was approximately \$1 trillion (\$27.1 trillion × 4%). The EU corporate bond market, on the other hand, totaled approximately €2.9 trillion, or \$3.1 trillion in volume (ESMA, 2023). This indicates total EU corporate bond settlement failures in value of \$93 billion (\$3.1 trillion × 3%) in 2022.

Security penalty rates for government and corporate bonds equal 0.10 and 0.20 basis points per day, respectively.[25] Consequently, the total savings in the EU from mitigating settlement failure would amount to \$12 million per annum (\$1 trillion × 0.001% + \$93 billion × 0.002%), assuming that penalties are paid on the following day after the transaction failure.

Public debt of the Euro Area and the United States constitutes 47% of total global public debt.[26] Scaling the results of these two economies globally, the total gain from reduced settlement failures is around **\$374 million** ((\$164 million + \$12 million) ÷ 47%) annually.

---

[23] Failed US bond settlement data is available on the Depository Trust & Clearing Corporation website under the section “Daily Total US Treasury Trade Fails.”

[24] European Union sovereign bond issuance data is from the International Capital Markets Association H2 2022 report “European Secondary Bond Market Data.”

[25] Euroclear December 2019 report, “CSDR Settlement Discipline Guide,” indicates daily penalty rates for late settlement of government and corporate bonds equal to 0.1 and 0.2 basis points per day, respectively.

[26] Public debt data by region is from the International Monetary Fund report “Global Debt Monitor 2023.”

Additionally, as previously mentioned, a 2% global fail rate would lead to hidden costs of approximately $3 billion annually (DTCC, 2021). Based on Table 1, public debt constitutes around 14% of the total RWA asset market size, excluding real estate to account only for financial assets.[27] Applying this estimate to settlement failures, a reduction in hidden costs would amount to savings of **$420 million** ($3 billion × 14%) per annum.

4.2.2. Reduced clearinghouse costs

Reduced clearing and settlement costs. We calculate the potential savings from implementing atomic settlement and removing a centralized counterparty. Adhering to the methodology outlined in section 4.1.3., the global revenue from clearing and settlement is projected at $15.8 billion. Fixed-income securities constitute 11% of the largest clearinghouse's – ICE Clear – revenue.[28] Assuming similar distribution across all central counterparties, we estimate that **$1.7 billion** of the global clearing and settlement revenue can be attributed to fixed fixed-income segment.

Reduced capital inefficiency costs. As discussed in Section 4.1.3, currently around $1.8 trillion is tied up as collateral for central counterparties globally. Since atomic settlement eliminates the need for collateral, unlocking this capital. We again attribute 11% of this collateral to the fixed-income segment, amounting to $198 billion. Using the current US Fed Funds rate of 5.5%[18] as the opportunity cost of capital, we estimate that capital inefficiency costs of **$10.9 billion** can be potentially eliminated through atomic settlement.

4.2.3. Reduced middle- and back-office costs

From our analysis in section 4.1.4, we estimate the global back office costs at $580 billion, which represents potential savings on middle- and back-office workers' salaries globally. To determine the portion of these savings attributable to public debt, we calculate the proportion of the public debt asset class to the total RWA market size, excluding physical assets. This proportion is approximately 14%.[27] Thus, the potential annual savings on middle-

---

[27] Calculated as the market size proportion of public debt ($92 trillion) to all financial asset classes ($660 trillion). Financial asset classes include all asset classes considered in our research, excluding real estate (see Table 1).

[28] Intercontinental Exchange report "Annual report 2022" states that revenue from clearing and settlement of fixed income securities constituted 11% of their total revenue in 2022.

and back-office costs within the fixed-income segment amount to **$81.2 billion** ($580 billion × 14%) per annum.

4.2.4. Reduced compliance costs

As discussed in section 4.1.5., global financial crime compliance costs total $206 billion, out of which 30% to 50% can be eliminated through asset tokenization, leading to potential savings ranging from $61.8 billion to $103 billion annually. We allocate 14% of these savings to public debt, reflecting its proportion of the total market size of financial assets[27]. As a result, we estimate the annual savings in financial crime compliance costs for public debt to be between **$8.7 billion** and **$14.4 billion**.

4.2.5. Economic surplus from increased trading volume

In this section, we examine the potential trade gains resulting from an increase in trading volume, focusing on welfare costs. The analysis considers that each potential market participant derives different private benefits or gains from trade. Participants engage in the market only if their gains surpass the associated costs, resulting in the realization of only a fraction of the potential market. Therefore, if market costs decrease due to the efficiency gains from implementing atomic settlement, more individuals are likely to participate, leading to heightened market liquidity and increased gains from trade (Glosten and Putnins, 2016). Figure 4 illustrates the gains.

In Figure 4 we show the graphic illustration of welfare gains calculation. We assume that in a perfect market, there exists an equilibrium price P. When we move from price $P+\frac{S_1}{2}$ to $P+\frac{S_2}{2}$, which is closer to the equilibrium price, we observe an increase in trading volume of $V_2 - V_1$. In other words, buyers whose private benefits lie between $P+\frac{S_1}{2}$ and $P+\frac{S_2}{2}$ have now joined the market. On the other hand, sellers who would not sell the bond at a price of $P-\frac{S_1}{2}$ will now sell at $P-\frac{S_2}{2}$.

Area $B_1 + B_2 + B_3$ represents the bid-ask spread earned by the liquidity providers, A is the buyer surplus, C is the seller surplus, and D + E + F + G is the deadweight loss. When the spread decreases from S_1 to S_2, the following occurs. Initial buyers keep surplus A and gain B_1 while new buyers gain D. Similarly, initial sellers keep surplus C, gain B_3, and new sellers gain F. Liquidity providers lose some surplus to buyers and sellers ($B_1 + B_3$) but gain surplus from new market participants (E). The deadweight loss reduces to area G and the reduction in the deadweight loss (D + E + F) is the economic surplus.

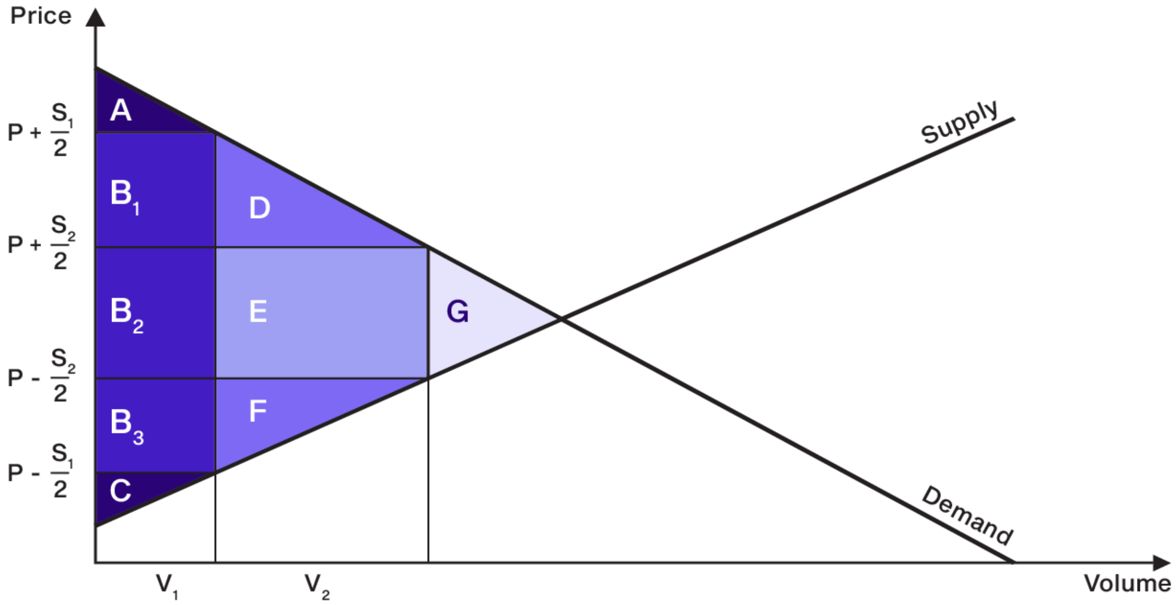


Figure 4
Illustration of welfare analysis.
This figure illustrates a welfare analysis of increased trading volume. As volume increases from V_1 to V_2, the bid-ask spread decreases from area $B_1 + B_2 + B_3$ to area B_2 + E. After the reduction of bid-ask spread, buyer surplus increases from area A to area A + B_1 + D. The seller surplus increases from area C to area C + B_3 + F. Deadweight loss is reduced from area D + E + F + G to area G. Based on study by Glosten and Putnins (2016).

To quantify these gains, we refer to a previous analysis of the Digital Finance Co-operative Research Centre (DFCRC, 2023). While an accurate estimation of gains from trade would ideally require a natural experiment, the referenced analysis examines changes in the market following the launch of the first UBS digital bond. Launched in 2022 on the SIX Swiss Exchange (SIX), this bond settles automatically using the SIX Digital Exchange Distributed Ledger. This allows us to analyze the market effects of the transition to atomic settlement. Comparing the market data of this digital bond with a similar traditional bond, the analysis by DFCRC reveals a 39% lower bid-ask spread for the digital bond and a 49% higher volume during the same period compared to the traditional bond.

To calculate the gains from trade, we first extract the bid-ask quotes for the 48 most liquid US Treasury bonds from Refinitiv Eikon Datastream, alongside the US sovereign bond market's average daily volume (ADV) of $630.9 billion.[29] We then calculate the average bid-ask spread of the 48 bonds equaling $0.358. Based on the potential 39% reduction in the bid-ask spread of digital bonds as reported by DFCRC (2023), we can then calculate that the adjusted average spread would be $0.218. For the calculation of gains of trade, we require the volume measured in a number of contracts. The average daily volume, when converted to contract numbers by dividing with the average midquote of the 48 bonds ($95.4), results in 6.6 billion daily contracts. With digital bonds potentially increasing volume by 49% (DFCRC, 2023), this figure rises to 9.9 billion contracts. The resulting gains from trade, incorporating these variables, equal **$239.5 billion** annually:

$$\left(\frac{S_1 + S_2}{2}\right) \times (V_2 - V_1) = \left(\frac{\$0.358 + \$0.218}{2}\right) \times (9.9\ billion - 6.6\ billion) \times 252\ = \$239.5\ billion$$

Table 6
Efficiency gains for public debt asset class.

This table reports the total efficiency gains by category of economic impact for the public debt asset class globally. The table includes the category of economic impact (*Category of Economic* Impact), the estimated efficiency gains in USD billions per annum (*Efficiency Gains*), and the implied savings per dollar tokenized in basis points (G_i) relative to the market size of the public debt asset class.

Category of Economic Impact	Efficiency Gains ($Bn p.a.)	G_i (bps)
Reduced penalties for settlement failures	$0.4	
Reduced hidden costs of settlement failures	$0.4	
Reduced operational costs of clearing & settlement	$1.7	
Reduced capital inefficiency costs	$10.9	
Reduced middle- and back-office costs	$81.2	
Reduced compliance costs	$8.7	
Economic surplus from increased trading volume	$239.5	
Total	$342.8	37.1

4.3. Public equities

4.3.1. Reduced settlement failures

In November 2023, there were settlement failures for 2.4 billion shares, valued at about $38.5 billion.[30] This was observed over 21 trading days, averaging daily failures of 114 million shares or $1.8 billion. For context, the daily average trading volume on major US equity

[29] US sovereign bond average daily volume (ADV) data is from the Securities Industry and Financial Markets Authority July 2023 report "2023 Capital Markets Fact Book."

[30] November 2023 data on settlement failures of public equities is available in the "Fails-to-Deliver Data" section on the US Securities Exchange Commission website.

markets (NYSE, NASDAQ, AMEX) in 2022 was 6.5 billion shares, totaling around $330 billion, implying that 1.7% of daily public equity transactions in the US fail to settle.

In Europe, the situation is even more pronounced, with the equity settlement failure rate at about 5%, as reported by the European Securities and Markets Authority (ESMA, 2023). The average daily volume of the European equity market in December 2023 was €38.3 billion (or $42.3 billion), suggesting average daily settlement failures of around $2.1 billion.[31]

Considering that the US and European public equities markets represent only 56% of the global volume, we can extrapolate that the global daily settlement failure rate amounts to approximately $7 billion (($1.8 billion + $2.1 billion) ÷ 56%), or $1.8 trillion annually.[32] Settlement penalty rates for public equities vary by market: 1 basis point in Europe,[33] 10 basis points in Australia,[13] and 2 basis points in Japan.[34] Assuming an average penalty rate of 5 basis points per day, the potential annual savings amount to **$900 million** ($1.8 trillion × 0.05%).

Furthermore, a global failure rate of 2% leads to hidden costs of about $3 billion annually (DTCC, 2021). Based on Table 1, public equities constitute approximately 17% of the total RWA asset market size, excluding real estate to account only for financial assets.[35] Applying this value, a reduction in these hidden costs would result in additional savings of **$510 million** ($3 billion × 17%) annually.

4.3.2. Reduced clearinghouse costs

Reduced clearing and settlement costs. Same as for FX transactions, we can estimate the savings from the implementation of atomic settlement and elimination of centralized counterparty. Following the same steps as described in section 4.1.3., we estimate that the global revenue from clearing, and settlement amounts to $15.8 billion. We estimate that around

---

[31] December 2023 average daily volume in the European equity market is from the Cboe "Data & Access" page "European Equities Market Share by Market."

[32] Public equity market volume by region is from the Securities Industry and Financial Markets Authority January 2024 report "Quarterly Report: US Equity & Related, 4Q23."

[33] Euroclear December 2019 report, "CSDR Settlement Discipline Guide," indicates daily penalty rates for late settlement of public equities equal to one basis point per day.

[34] Penalty rate for public equity settlement failures in Japan is from the Japan Securities Clearing Corporation page "Assumption of Obligation" under the section "Fail."

[35] Calculated as the market size proportion of public equities ($109 trillion) to all financial asset classes ($660 trillion). Financial asset classes include all the asset classes considered in our research, excluding real estate (see Table 1).

25% of global clearing and settlement revenue can be ascribed to equities.[36] Thus, atomic settlement can potentially reduce costs associated with clearing and settlement of equities by **$4 billion** per annum.

Reduced capital inefficiency costs. Additionally, we calculate the capital inefficiency cost stemming from locked-up capital in initial margins and default funds. As mentioned in section 4.1.3., in the third quarter of 2023 the total tied-up collateral amounted to $1.8 trillion[17] of which we attribute 25% to the clearing and settlement of public equities. Using the current 5.5% US Fed Fund rate[18] as the opportunity cost of capital, the capital inefficiency cost of equities amounts to **$24.8 billion** annually.

4.3.3. Reduced middle- and back-office costs

As detailed in section 4.1.4, an estimated $580 billion could be saved annually on the labor costs associated with middle- and back-office employees' salaries. We calculate that 17% of this figure is attributable to public equities, based on their market capitalization as a proportion of the total financial assets market size[35]. Therefore, we project an annual reduction in the middle- and back-office costs for public equities of approximately **$98.6 billion**.

4.3.5. Reduced compliance costs

As discussed in section 4.1.5., global financial crime compliance costs total $206 billion, out of which 30% to 50% can be eliminated through asset tokenization, leading to potential savings ranging from $61.8 billion to $103 billion annually. Applying the proportion of public equities' market size, which is 17% of the total financial assets market size, we attribute this percentage to the savings[35]. Consequently, we estimate the annual savings in compliance costs for public equities to be between **$10.5 billion** and **$17.5 billion**.

4.3.5. Economic surplus from increased trading volume

As discussed in section 4.2.5, the economic benefits of increased trading volume could be best observed by a natural experiment; however, due to the absence of pilot projects, the benefit can be extrapolated by looking at the changes observed during an event of similar importance. To assess the gains from trade for public equity, we use the changes observed after

---

[36] CME Group report "CME Group Annual Report 2022" states that public equities clearing and settlement revenue constituted 24.5% of their total revenue in 2022.

the implementation of the NYSE Autoquote in 2003 as this event can act as a proxy for the implementation of atomic settlement (DFCRC, 2023). Before the implementation of Autoquote, trading required a lot of manual labor as specialists were needed to match orders and update quotes. The revolution in 2003 provided an opportunity to decrease the need for specialists as with changes in the limit order book, the new quote would be spread automatically (Hendershott et al., 2011). The initial automation of quotes had major benefits and drastically changed the capacity of trading as well as brought major efficiency gains which were reflected in the decrease in the bid-ask spread and an increase in the trading volume. The average bid-ask spread decreased by around 50%, whilst the average daily trading volume grew by 5% (DFCRC, 2023).

To calculate the potential gains from trade, we extract year-to-date bid-ask quotes for the 1,000 largest stocks by trade volume in the US from Refinitiv Eikon Datastream. We then calculate the average bid-ask spread for these stocks amounting to 2.1 cents. The average daily volume of US equities equals around 6.2 billion contracts.[37] Assuming a similar effect from atomic settlement as the abovementioned gains from implementing Autoquote, the new bid-ask spread would be reduced to 1.05 cents (2.1 cents × 50%) and the average daily volume would increase to 6.5 billion (6.2 billion × 1.05), an increase of 0.3 billion from the current value. Using the same formula as before, we can calculate the gains from trade of $4.7 million daily, or $1.2 billion per annum.

$$\left(\frac{S_1 + S_2}{2}\right) \times (V_2 - V_1) = \left(\frac{\$0.021 + \$0.0105}{2}\right) \times 0.3\ billion \times 252 = \$1.2\ billion$$

Lastly, since the US stock market accounts only for 44.9% of the total public equity market we scale these gains from trades globally and acquire an estimated economic gain of **$2.7 billion** annually.[38]

[37] December 2023 average daily volume in the US equity market is from the Cboe "Data & Access" page "U.S. Equities Market Volume Summary."

[38] Public equity market size by region is from the Securities Industry and Financial Markets Authority January 2024 report "Quarterly Report: US Equity & Related, 4Q23."

4.3.6. Increased total asset value

Increasing operational efficiency in settlement processes is likely to increase market liquidity by attracting more participants and increasing trading volumes. This rise in liquidity, along with lower market participation costs, is expected to increase asset values due to the liquidity return premium. Investors price assets based on the required return after factoring in trading costs; hence, higher trading costs lead to lower asset prices. Improvements in liquidity or reductions in trading costs will lower the nominal required rate of return, thereby increasing asset values. For financial assets used in financing (like equities, bonds, and loans), a lower nominal rate also means reduced funding costs for capital market users, potentially leading to more investment and economic growth.

To estimate the total potential increase in an asset value, we apply the perpetual dividend asset pricing model, expressed as $P = \frac{d}{E[r]-g}$ where d denotes the perpetual dividend per period, $E[r]$ is the expected return before costs, and g is the growth rate of dividends. Additionally, we incorporate insights from Amihud and Mendelson's (1986) research, which postulates that the expected before-cost return, E[r] can be calculated as $r + \mu \cdot S$ where r is the required return after costs, μ is the expected trading frequency, and S is the trading cost, or the bid-ask spread, that arises from market participation costs, clearing costs, settlement costs, etc. Since tokenization eliminates or significantly reduces some of these costs, the trading costs decrease and, consequently, asset prices increase.

We find the average price of US stocks by calculating the mean price of all stocks included in the largest US stock index, FT Wilshire 5000. As of January 11, 2024, the average price of 3,166 stocks included in the index was $69.21. The average dividend yield of these stocks equals 1.45%, or $1, and the average trading cost of stocks listed on the US Nasdaq is 10.21 basis points (Frazzini et al., 2018). The expected trading frequency can be expressed as $\mu = \frac{Annual\ turnover}{Market\ capitalization}$. Given the US market capitalization of $46.2 trillion and the average monthly turnover of $6.9 trillion, the implied trading frequency equals 1.79 ($\frac{\$6.9\ trillion \times 12}{\$46.2\ trillion}$). Using the long-term average S&P 500 index return of approximately 10% as a proxy for the average US stock market return, we can rearrange the formulas to calculate the implied rate of growth, $g = r + \mu \cdot S - \frac{d}{P} = 10\% + 1.79 * 0.001 - 1.4\% = 8.7\%$.

Conservatively assuming a 20% reduction in trading costs, or approximately 2 basis points, we can redo the calculation. Using the same growth rate of 8.7%, the new asset price would equal $P = \frac{d}{r + \mu \times S - g} = \frac{1}{10\% + 1.79 \times 0.0008 - 8.7\%} = \$70.75$ which amounts to an increase in asset value of 2.22%. Applying this increase to the whole US stock market with a market capitalization of $46.2 trillion, the total increase in asset value would equal $1.03 trillion. As previously, we scale these results globally since the US accounts only for 42.5% of the total public equity market and arrive at a total potential increase in asset value of **$2.4 trillion.**

Although compared to other efficiency gains this may seem extremely large, this increase stems from reduced trading costs, for which we accounted in the previous sections (hence, we do not include this value in the subsequent calculations). In other words, this number can be regarded as the present value of all future trading cost savings. For this reason, this is a one-off effect rather than an annual saving. It is also important to note that trading costs in other, less efficient markets might be significantly larger than in the US, hence the real increase would likely be even larger.

Table 7
Efficiency gains for public equities asset class.
This table reports the total efficiency gains by category of economic impact for public equities globally. The table includes the category of economic impact (*Category of Economic* Impact), the estimated efficiency gains in USD billions per annum (*Efficiency Gains*), and the implied savings per dollar tokenized in basis points (G_i) relative to the market size of public equities.

Category of Economic Impact	Efficiency Gains ($Bn p.a.)	G_i (bps)
Reduced penalties for settlement failures	$0.9	
Reduced hidden costs of settlement failures	$0.5	
Reduced operational costs of clearing & settlement	$4.0	
Reduced capital inefficiency costs	$24.8	
Reduced middle- and back-office costs	$98.6	
Reduced compliance costs	$10.5	
Economic surplus from increased trading volume	$2.7	
Total	$141.9	13.0

4.4. Real estate

4.4.1. Reduced closing costs

Closing costs in real estate transactions encompass various fees and expenses incurred during the process of buying or selling property. These costs are divided into several categories, including loan origination fees, appraisal fees, title searches, title insurance, surveys, taxes, deed recording fees, and credit report charges. Traditionally, these expenses can add up to a significant portion of the transaction value, often ranging between 2% to 5% of the property's purchase price.

The adoption of DLT, such as blockchain, introduces the potential for significant reductions in these costs through mechanisms like atomic settlement. Atomic settlement could potentially eliminate the need for intermediaries, such as escrow agents, thereby eliminating or significantly reducing the associated fees. Additionally, the transparency and security provided by DLT could streamline the title search and insurance process, further cutting down costs. By digitizing and automating these traditionally manual and time-consuming processes, DLT and tokenization present an opportunity to make real estate transactions more efficient and cost-effective.

Table 8
Average real estate closing costs in the US.

This table reports the size of average closing costs in the United States by 13 different cost positions in descending order. The table includes the rank (*n*), the cost position (*Cost Position*) and the size of the cost position relative to total closing costs position (*Percentage of Total Closing Costs*). Data based on a national survey of more than 50,00 participants by Real Estate Bees "Real Estate Closing Costs Statistics by State 2024."

n	Cost Position	Percentage of Total Closing Costs
1	Realtor commission	11.2%
2	Seller concessions	10.5%
3	Title service fees	9.6%
4	Transfer tax	9.0%
5	Title insurance fees	8.0%
6	Property taxes	7.6%
7	Attorney fees	7.4%
8	Escrow service fees	7.1%
9	Home warranty	6.8%
10	HOA fees	4.8%
11	Pre-paid taxes	3.8%
12	Earnest money	1.2%
13	Other fees	13.0%

A recent national survey of more than fifty thousand real estate professionals in the US estimated the average closing costs (see Table 8).[39] They indicate 19 different cost positions in total closing costs. Out of these 19 cost positions, we identify 5 that could potentially be eliminated through the use of DLT: title service fees, title insurance fees, escrow service fees, earnest money, and attorney fees. Any costs associated with the search or insurance of the title

[39] Average closing costs data is from the Real Estate Bees report "Real Estate Closing Costs Statistics by State 2024."

are eliminated since the title is recorded on a publicly available immutable ledger, allowing for transparent tracking of title history. This reduces the risk of fraud and errors, making title verification more efficient and less reliant on costly insurance and recording processes. Smart contracts eliminate escrow fees and earnest money, ensuring that funds are securely held and only released when predefined conditions are met and, consequently, eliminating any counterparty risk. Similarly, tokenization of real estate would significantly reduce attorney fees by automating certain legal processes, such as contract review and compliance checks, leading to significant savings in legal costs associated with document preparation, verification, and transaction execution.

These five cost positions constitute 33.3% or exactly one-third of total average closing costs in the US. The National Association of Realtors estimates that the average closing costs for a single-family property was $6,905 in 2021, or approximately 1.8% of the median house price of $389,800 in the US.[40] Hence, the potential cost savings equal one-third of this, or 0.6%. The global real estate transaction volume is estimated to be around $8.3 trillion for residential estate[41] and $1.14 trillion for commercial estate.[42] Assuming that these cost savings apply equally both to residential and commercial estate, we apply the 0.6% savings and estimate potential efficiency gains of **$56.6 billion** per annum.

4.4.2 Reduced operational costs

The real estate investment sector is burdened by inefficient processes related to transactions and record management, where administrative tasks account for a significant portion of operational expenses, ranging from 50-75%.[43] The labor-intensive nature of these tasks, such as trade recording, settlement, and property data management, necessitates substantial labor costs. Tokenization offers automating many of these cumbersome processes, thus potentially reducing or even eliminating a large share of the operating costs.

---

[40] Real estate closing costs data is from the National Association of Realtors May 10, 2022, report “Average Closing Costs By State.” Median home price data is from the National Association of Realtors website page “Existing-Home Sales.”

[41] Global residential real estate transaction volume data is available on the Statista website page “Residential Real Estate Transactions – Worldwide.”

[42] Global commercial real estate transaction volume data is from the CBRE February 8, 2023, article “Global Investment Declines Sharply in Q4 2022.”

[43] DigiShares November 2022 report “Real Estate Tokenization. An Industry Report 2022” states that administrative work represents 50% to 75% of the issuer’s total operating costs.

According to Moody's analysis, leveraging blockchain technology could lead to a 10-20% reduction in workforce expenses, translating into an estimated annual savings of between $840 million to $1.7 billion within the US housing market alone.[44] We extrapolate these values to the global real estate market (of which the US accounts for 19%) and estimate the efficiency gains to be between **$4.4 billion** and **$8.9 billion** per annum.

4.4.3 Reduced listing costs

The process of publicly listing Real Estate Investment Trusts (REITs) is both time-intensive and financially demanding, often extending beyond two years and incurring costs that represent 3% to 10% of the REIT's total market capitalization[43]. These burdensome requirements lead many real estate investment entities to operate within private markets instead. Tokenization of REITs, however, would enable streamlining the listing procedure, thus diminishing the manual workload and associated expenses. Reduction in these costs would likely also increase liquidity within the public real estate sector.

To calculate the average savings per annum, we first find the average number of REITs listed per annum. We obtain the number of REITs listed each year between 1997 and 2023 from the Thomson Reuters Tick History database. During this period, 175 REITs started trading, an average of 6.5 REITs per annum.[45]

We then calculate the market capitalization of an average REIT. The FTSE Nareit All REITs equity market capitalization as of January 31, 2024, reached $1.3 trillion.[46] This index consists of 195 publicly traded US REITs, indicating an average market capitalization of $6.7 billion for individual REITs.

We multiply the annual listings with the average market capitalization and obtain the total average listing value of REITs which equals $43.5 billion per year. We then apply the 3% to 10% estimated reduction in listing costs. This results in average listing costs of $1.3 billion to $4.4 billion per annum in the US. Considering that the US has a more developed REIT market compared to other markets, we conservatively assume that the US fully constitutes the

[44] Effects of tokenization on US mortgage industry is reviewed in CoinDesk’s April 12, 2018, article “Moody's: Blockchain Could Save US Mortgage Industry $1 Billion.”

[45] The database does not include information about REITs that were both listed and delisted during this period. Consequently, the real average number of annual REIT listings is likely higher.

[46] REITs market capitalization data is from the Nareit January 31, 2024, report “REIT Industry Fact Sheet.”

REIT market. This indicates global REIT listing costs of **$1.3 billion** which could potentially be saved through tokenization of REITs and automation of manual processes.

Table 9
Efficiency gains for real estate asset class.

This table reports the total efficiency gains by category of economic impact for real estate asset class globally. The table includes the category of economic impact (*Category of Economic* Impact), the estimated efficiency gains in USD billions per annum (*Efficiency Gains*), and the implied savings per dollar tokenized in basis points (G_i) relative to the market size of real estate asset class.

Category of Economic Impact	Efficiency Gains ($Bn p.a.)	G_i (bps)
Reduced closing costs	$56.6	
Reduced operational costs	$4.4	
Reduced listing costs	$1.3	
Total	$62.3	1.6

4.5. Extrapolation

Based on our analysis, we estimate that the annual efficiency gains in a fully tokenized economy would amount to $857 billion per annum for forex exchange and $391 billion per annum for public debt instruments. Public equities would generate savings worth $200 billion annually but efficiency gains for real estate amount to $62 billion per annum. Based on these values, we can calculate the G_i variable by dividing the quantified benefits by the respective market capitalization of each asset class. The implied G_i variable for FX, public debt, public equity, and real estate asset classes equal 98, 42, 18, and 2 basis points (bps), respectively.

We determine the G_i variable for the unknown asset classes by using data from the ISSA (2023) survey as a benchmark for extrapolation, as shown in Table 10. We first divide the G_i values of known asset classes with the values from the survey to determine the value of 1%. We then average these 1% values across the four asset classes and use this average as a baseline to estimate the G_i values for asset classes where the values are not directly available by multiplying them with the survey percentage value.

Based on our analysis, foreign exchange has both the largest savings per dollar tokenized and the largest efficiency gains in dollar terms, as can be seen in Appendix C. This is likely due to the many existing inefficiencies (intermediaries, bid-ask spreads, manual back-office processes) as well as the huge daily spot market turnover of $2.1 trillion (see Table 1). The inefficiencies create additional costs, which are amplified by each transaction. Real estate, on the other hand, has the smallest savings per dollar tokenized. We believe the first reason for this is the non-fungible nature of physical assets like real estate, which creates more hurdles in tokenization and settlement compared to fungible assets like public equities. Another reason might be that a real estate purchase usually constitutes a relatively large amount of a person's total income (often exceeding it). For both of these reasons, a person might be more inclined to have intermediaries to help with the purchasing process, even if it creates economic inefficiencies.

Table 10

Extrapolation of savings per dollar tokenized (G_i).

This table reports the extrapolation process of the savings per dollar tokenized variable for each real-world asset class. The measures include the total annual efficiency gains per dollar tokenized in basis points as calculated in Section 4 (*Calculated G_i*), the results from the International Securities Services Association report (*Industry Expectation*), the extrapolated G_i value (*Extrapolated G_i*), and the implied efficiency gains in USD billions per annum (*Efficiency Gains*). *Industry Expectation* data is obtained from page 25 of the International Securities Services Association report "DLT in The Real World 2023."

Asset class	Calculated G_i (bps)	Industry Expectation (%)	Extrapolated G_i (bps)	Efficiency Gains ($Bn p.a.)
Foreign exchange	93.2	15.0		812.6
Public debt	37.1	9.0		342.8
Public equities	13.0	6.0		141.9
Real estate	1.6	6.0		62.3
Carbon credits		16.0	51.1	9.7
Private equity		10.0	31.9	37.4
Private debt		9.0	28.8	418.9
OTC derivatives		13.0	41.5	86.0
Investment funds		13.0	41.5	262.0
Commodities		6.0	19.2	245.9
Total				2,419.5

5. Tokenizable fraction (F_i)

To calculate the potentially tokenized fraction or the projected percentage of each asset class that could be tokenized, we reference the findings from the leading industry report by Kumar et al. (2022) as the basis. This report provides valuable projections on the tokenization prospects by 2030 for various asset classes, including real estate, bonds, investment funds, and equities. According to the report, the tokenized value of real-world assets will reach $16 trillion by 2030 under a conservative estimation. Conversely, an optimistic outlook suggests this value might reach as high as $68 trillion. Our analysis adopts these figures as the lower and upper bounds of our projections, respectively. Additionally, we introduce a base case scenario, calculated as the mean of these two estimates, amounting to $42 trillion.

Table 11

Panel A: Tokenized fraction by asset class.

Panel A reports the estimated tokenized fraction by 2030 for real-world asset classes. The name of the asset class (*Asset* Class), the number of platforms tokenizing the respective asset class (*Platforms*), the relative percentage of platforms tokenizing the respective asset class (*% of Total Platforms*), market capitalization in USD trillion (*Market Size*), and the estimated tokenized value by 2030 in USD trillion if the asset classes were tokenized at rates proportional to the relative number of platforms (*Tokenized Value*).

Asset Class	Platforms	% of Total Platforms[47]	Market Size ($Tn)	Tokenized Value ($Tn)
Real estate	35	25.9%	379.7	98.4
Private debt	58	43.0%	145.7	62.6
Commodities	10	7.4%	128.3	9.5
Public equities	25	18.5%	109	20.2
Public debt	27	20.0%	92.4	18.5
Foreign exchange	16	11.9%	87.2	10.3
Investment funds	10	7.4%	63.1	4.7
OTC derivatives	5	3.7%	20.7	0.8
Private equity	25	18.5%	11.7	2.2
Carbon credits	6	4.4%	1.9	0.1
Total	135		1039.7	227.2

Panel B: Scenarios for the tokenized fraction (F_i).

Panel B reports the estimated tokenized fraction by 2030 for each real-world asset class. The tokenized fraction is divided into four scenarios: (1) conservative scenario, (2) base case scenario, (3) optimistic scenario, and (4) full-scale scenario.

Asset Class	Conservative Scenario F_i	Base Case Scenario F_i	Optimistic Scenario F_i	Full-scale Scenario F_i
Real estate	1.8%	4.8%	7.8%	100%
Private debt	3.0%	7.9%	12.9%	100%
Commodities	0.5%	1.4%	2.2%	100%
Public equities	1.3%	3.4%	5.5%	100%
Public debt	1.4%	3.7%	6.0%	100%
Foreign exchange	0.8%	2.2%	3.5%	100%
Investment funds	0.5%	1.4%	2.2%	100%
OTC derivatives	0.3%	0.7%	1.1%	100%
Private equity	1.3%	3.4%	5.5%	100%
Carbon credits	0.3%	0.8%	1.3%	100%
Tokenized value ($Tn)	16.0	42.0	68.0	1039.7

[47] The sum of percentages amount to more than hundred percent since there are platforms that tokenize more than one asset class.

To calculate the F_i variables for the three scenarios, we first create an extensive list of 135 tokenization platforms and protocols.[48] We then determine the proportion of platforms that tokenize each asset class by dividing each value by 135 or the total number of platforms. We use this to gauge which classes are most tokenized in practice. These proportions can be considered as the ideal F_i values. We multiply these ideal percentages by the market sizes of their respective asset classes to estimate the total value of tokenization in an ideal scenario, which amounts to $213.6 trillion, as shown in Table 11 (Panel A). Next, we scale these values down to match the total values of conservative, base case, and optimistic scenarios.[49] The results for all three scenarios are compiled in Table 11 (Panel B).

6. Aggregation of economic gains and discussion

To estimate the total economic benefit of tokenizing each asset class, we first multiply the market size (V_i) of each asset class by the corresponding economic gains per dollar tokenized (G_i). The product of these two variables is the full-scale potential economic savings if all asset classes were to be completely tokenized. Next, we scale these figures down based on the realistically tokenizable fraction (F_i) under conservative, base, and optimistic scenarios.

Our analysis, summarized in Table 12, reveals the substantial economic savings potential of real-world asset tokenization, which would amount to at least $2.4 trillion per annum in a fully tokenized financial system. Under the most conservative scenario, we project the total economic savings from RWA tokenization to be around $31 billion annually by 2030. This figure increases to $81 billion in the base-case scenario and further to $130 billion per annum in the most optimistic scenario.

The analysis highlights that the three largest asset classes to benefit from full-scale tokenization are foreign exchange with potential savings of $857 billion as well as private debt and public debt with savings of $478 billion and $391 billion, respectively. These findings underscore the significant economic impact that full-scale tokenization would have across various asset classes.

---

[48] Major tokenization platforms and protocols include Securitize, Tokeny, Polymath, and ADDX. A full list of platforms is available in Appendix A.

[49] For instance, in the conservative scenario, the F_i variable for carbon credits is calculated by taking the ideal scenario's F_i of 4.4%, then adjusting it in proportion to the scenario's total market value ($16 trillion over $214 trillion), resulting in 0.3%.

Table 12

Global economic value-add (EVA) of RWA tokenization by asset class.

This table reports the total economic value-add of ten real-world asset (RWA) classes across four scenarios (column 1): the (1) full-scale, (2) base-case, (3) optimistic, and (4) conservative scenario. In columns 1 to 11 we report the market size (V_i), savings per dollar tokenized (G_i), tokenizable fraction (F_i), and their product ($V_i \times G_i \times F_i$), economic value-add (EVA) for each asset class in each scenario. The last column (*Total*) indicates the total EVA for all 10 asset classes.

		Real estate	Private debt	Commodities	Public equities	Public debt	Foreign exchange	Investment funds	OTC derivatives	Private equity	Carbon credits	Total
	V_i ($Tn)	379.7	145.7	128.3	109	92.4	87.2	63.1	20.7	11.7	1.9	
	Gi (bps)	1.6	28.8	19.2	13.0	37.1	93.2	41.5	41.5	31.9	51.1	
Full-scale	Fi (%)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
	EVA ($Bn)	62.3	418.9	245.9	141.9	342.8	812.6	262.0	86.0	37.4	9.7	2,419.5
Conservativ	Fi (%)	1.8%	3.0%	0.5%	1.3%	1.4%	0.8%	0.5%	0.3%	1.3%	0.3%	
	EVA ($Bn)	1.1	12.7	1.3	1.9	4.8	6.8	1.4	0.2	0.5	0.0	30.7
Base case	Fi (%)	4.8%	7.9%	1.4%	3.4%	3.7%	2.2%	1.4%	0.7%	3.4%	0.8%	
	EVA ($Bn)	3.0	33.3	3.4	4.9	12.7	17.8	3.6	0.6	1.3	0.1	80.5
Optimistic	Fi (%)	7.8%	12.9%	2.2%	5.5%	6.0%	3.5%	2.2%	1.1%	5.5%	1.3%	
	EVA ($Bn)	4.8	53.9	5.5	7.9	20.5	28.8	5.8	1.0	2.1	0.1	130.3

The provided figures represent the gross benefits, not the net gains, of transitioning from traditional finance (TradFi) to decentralized finance (DeFi). This transition also involves various costs, such as the expenses for developing technology to connect TradFi and DeFi systems, implementing new compliance measures, and investing in education and training programs, among others. Over time, however, these initial costs are expected to decrease, while the projected economic savings from the transition are anticipated to stay consistent.

Tokenization of real-world assets holds significant potential for enabling efficiencies in global financial markets. To fully harness this potential, however, it is imperative to establish a globally harmonized legal framework and develop standards for interoperability across both DLT-based and traditional systems. This will create a cohesive ecosystem facilitating seamless interaction worldwide. Moreover, the advent of DLT-based payment methods, including CBDCs, is essential for enabling efficient settlement and transfer processes. Realizing the economic benefits of tokenization demands substantial investments from governments, regulatory bodies, and market participants alike. Thus, initiatives such as regulatory sandboxes and task forces are vital early steps toward the adoption of decentralized market structures and RWA tokenization.

We acknowledge that the novelty of the topic requires a higher reliance on assumptions and approximations than is typical for empirical research, which traditionally draws on historical data to identify relations. Consequently, due to the scarcity of academic literature on this subject, we derive certain assumptions and estimates from a variety of non-traditional sources, including blog posts, presentations, interviews, and other grey literature. This approach is informed by the fact that RWA tokenization has not yet materialized on a significant scale, and as such, our goal is to estimate the potential magnitude of economic savings rather than to ascertain an exact figure.

Due to the scarcity of available data and the constraints imposed by our research timeframe, conducting a comprehensive analysis of efficiency gains for each asset class individually was beyond our capacity. Consequently, we focus on calculating the values for asset classes that are both largest by market capitalization and have the most precise data available. We then extrapolate these findings to other asset classes, drawing upon the ISSA report “DLT in The Real Word 2023.” While this survey reflects insights from industry professionals, we recognize that the responses may represent educated guesses rather than precise estimates, underscoring a potential limitation in the accuracy of our extrapolations. Considering we already include 4 major asset classes in our analysis, only the remaining 6 asset classes are impacted by extrapolation, corresponding to 22% of the RWA market size.

7. Conclusions

We contribute to the very novel and increasingly relevant area of RWA tokenization. This is, to our knowledge, the first study to assess the global economic impact of RWA tokenization across different asset classes. We find that RWA tokenization could yield up to $2.4 trillion annually in economic benefits, offering a compelling argument for the urgent creation of regulatory frameworks to accommodate this innovation. Considering a realistic tokenization adoption rate, these savings could globally amount to around $81 billion per annum by 2030 in the base case scenario.

We show that financial asset classes with less efficient markets stand to gain the most from RWA tokenization. These include asset classes like foreign exchange and public debt. Conversely, tokenization of physical assets such as real estate might not yield substantial benefits due to the constrained scope for automation, which implies that many inefficient manual processes would remain unaddressed, as well as low transaction frequency. Nonetheless, physical assets would benefit from significantly higher liquidity due to fractionalization and reduced entry barriers for investors.

Ultimately, the results imply that RWA tokenization offers a pivotal change in the current market structure. The value of tokenized assets is already experiencing rapid growth, although currently only across a few asset classes. There are still several limitations restraining the rapid adoption of RWA tokenization, but the development of effective and unified legislation may eliminate them. We urge policymakers to adopt tokenization as a means to drive economic growth, enhance financial inclusion, and integrate digital and traditional assets seamlessly.

References

Amihud, Y., and Mendelson H. (1986). Asset pricing and the bid-ask spread. *Journal of Financial Economics*, *17*, 223–249.

Auer, R. (2019). Embedded supervision: how to build regulation into decentralized finance. *Cryptoeconomic Systems*, *2*, 1–46.

Bank for International Settlements. (2022). OTC foreign exchange turnover in April 2022. *BIS Triennial Central Bank Survey 2022*, 1–21.

Baum, A. (2021). Tokenization—The future of real estate investment? *The Journal of Portfolio Management*, *47*, 41–61.

Bech, M., and Garratt, R. (2017). Central bank cryptocurrencies? *BIS Quarterly Review, September 2017*, 55–70.

Bech, M., Hancock, J., Rice, T., and Wadsworth, A. (2020). On the Future of Securities Settlement. *BIS Quarterly Review, March 2020*, 67–83.

Blemus, S., and Guégan, D. (2020). Initial crypto-asset offerings (ICOs), tokenization, and corporate governance. *Capital Markets Law Journal*, *15*, 191–223.

Carapella, F., Chuan, G., Gerszten, J., Hunter, C., and Swem, N. (2023). Tokenization: overview and financial stability implications. *Finance and Economics Discussion Series*, 1–29.

Chen, M.A., Wu, Q., and Yang, B. (2019). How valuable is FinTech innovation? *The Review of Financial Studies*, *32*, 2062–2106.

Chiu, J., and Koeppl, T.V. (2019). Blockchain-based settlement for asset trading. *The Review of Financial Studies*, *32*, 1716–1753.

Chod, J., and Lyandres, E. (2023). Product market competition with crypto tokens and smart contracts. *Journal of Financial Economics*, *149*, 73–91.

Chod, J., Trichakis, N., and Yang, S. A. (2022). Platform tokenization: Financing, governance, and moral hazard. *Management Science*, *68*, 6411–6433.

Cong, L.W., and He, Z. (2019). Blockchain disruption and smart contracts. *The Review of Financial Studies*, *32*, 1754–1797.

Cong, L.W., Li, Y., and Wang, N. (2021). Tokenomics: Dynamic adoption and valuation. *The Review of Financial Studies*, *34*, 1105–1155.

Cong, L.W., Li, Y., and Wang, N. (2022). Token-based platform finance. *Journal of Financial Economics*, *144*, 972–991.

Digital Finance Co-operative Research Centre. (2023). The economic impact of a Central Bank Digital Currency in Australia. *Unpublished working paper*.

Ekberg, J., Chia, T.Y., and Ho, M. (2021). Unlocking $120 Billion Value in Cross-border Payments — How Banks Can Leverage Central Bank Digital Currencies. *Report for Oliver Wyman*, 1–34.

European Securities and Markets Authority. (2023). TRV Risk Monitor. *ESMA Report on Trends, Risks and Vulnerabilities*, *2023-2*, 1–43.

Fairfield, J.A.T. (2022). Tokenized: The law of non-fungible tokens and unique digital property. *Indiana Law Journal*, *97*, 1262–1313.

Foley, S., O'Neill, P., and Putniņš, T.J. (2023). Applying 'Automated Market Makers' to Traditional Financial Markets. *Unpublished working paper*.

Frazzini, A., Israel, R., and Moskowitz, T.J. (2018). Trading Costs. *Unpublished working paper*.

Garbade, K.D., Keane, F.M., Logan, L., Stokes, A., and Wolgemuth, J. (2010). The Introduction of the TMPG Fails Charge for U.S. Treasury Securities. *Economic Policy Review*, 45–71.

Garcia-Teruel, R.M., and Simón-Moreno, H. (2021). The digital tokenization of property rights, a comparative perspective. *Computer Law & Security Review*, *41*, 1–16.

Glosten, L.R., and Putniņš, T.J. (2016). Welfare Costs of Informed Trade. *AFA 2016 San Francisco Meetings*, *Columbia Business School Research Paper*, 16–58.

Glowka, M., and Nilsson, T. (2022). FX settlement risk: an unsettled issue. *BIS Quarterly Review*, *December 2022*, 75–80.

Gryglewicz, S., Mayer, S., and Morellec, E. (2021). Optimal financing with tokens. *Journal of Financial Economics*, *142*, 1038–1067.

Heines, R., Dick, C., Pohle, C., and Jung, R. (2021). The tokenization of everything: Towards a framework for understanding the potentials of tokenized assets. *In The 2021 Pacific Asia Conference on Information Systems (PACIS) Proceedings*, 1–14.

Hendershott, T., Jones, M.C., and Menkveld, A.J. (2011). Does algorithmic trading improve liquidity? *Journal of Finance*, *66*, 1–33.

Howell, S.T., Niessner, M., and Yermack, D. (2020). Initial coin offerings: Financing growth with cryptocurrency token sales. *The Review of Financial Studies*, *33*, 3925–3974.

Kumar, S., Suresh, R., Liu, D., Kronfellner, B., and Kaul, A. (2022). Relevance of on-chain asset tokenization in 'crypto winter'. *Report for Boston Consulting Group & ADDX*, 1–17.

Laurent, P., Chollet, T., Burke, M., and Seers, T. (2018). The tokenization of assets is disrupting the financial industry. *Triannual Insights from Deloitte*, *19*, 62–67.

Layr, A.K. (2021). Tokenization of assets: Security tokens in Liechtenstein and Switzerland. *Milan Law Review*, *2*, 45–72.

Li, X., Wu, X., Pei, X., and Yao, Z. (2019). Tokenization: Open asset protocol on blockchain. *In 2019 IEEE 2nd International Conference on Information and Computer Technologies (ICICT)*, 204–209.

Liu, P.T.S. (2016). Medical record systems using blockchain, big data, and tokenization. *In Information and Communications Security: 18th International Conference (ICICS) Proceedings*, 254–261.

Nassr, I.K. (2020). The tokenization of assets and potential implications for financial markets. *Organization for Economic Co-operation and Development*, 1–58.

Ross, O., Jensen, J.R., and Asheim, T. (2019). Assets under tokenization: Can blockchain technology improve post-trade processing? *In 2019 Fortieth International Conference on Information Systems (ICIS) Proceedings*, 1–9.

Sazandrishvili, G. (2020). Asset tokenization in plain English. *Journal of Corporate Accounting & Finance*, *31*, 68–73.

Schwarcz, S.L. (2022). Next-generation securitization: NFTs, tokenization, and the monetization of 'Things'. *Duke Law School Public Law & Legal Theory Series*, *2022-13*, 967–1003.

Sockin, M., and Xiong, W. (2023). Decentralization through tokenization. *The Journal of Finance*, *78*, 247–299.

Tian, Y., Lu, Z., Adriaens, P., Minchin, R.E., Caithness, A., and Woo, J. (2020). Finance infrastructure through blockchain-based tokenization. *Frontiers of Engineering Management*, *7*, 485–499.

Treat, D., Brodersen, C., Blain, C., and Kurbanov, R. (2017). Banking on blockchain. A value analysis for investment banks. *Report for Accenture Consulting*, 5–6.

Uzsoki, D. (2019). Tokenization of Infrastructure: A Blockchain-Based Solution to Financing Sustainable Infrastructure. *International Institute for Sustainable Development*, 1–34.

Woxholth, J., Zetzsche, D.A., Buckley, R.P., and Arner, D.W. (2023). Competing claims to crypto-assets. *Uniform Law Review*, *28*, 226–246.

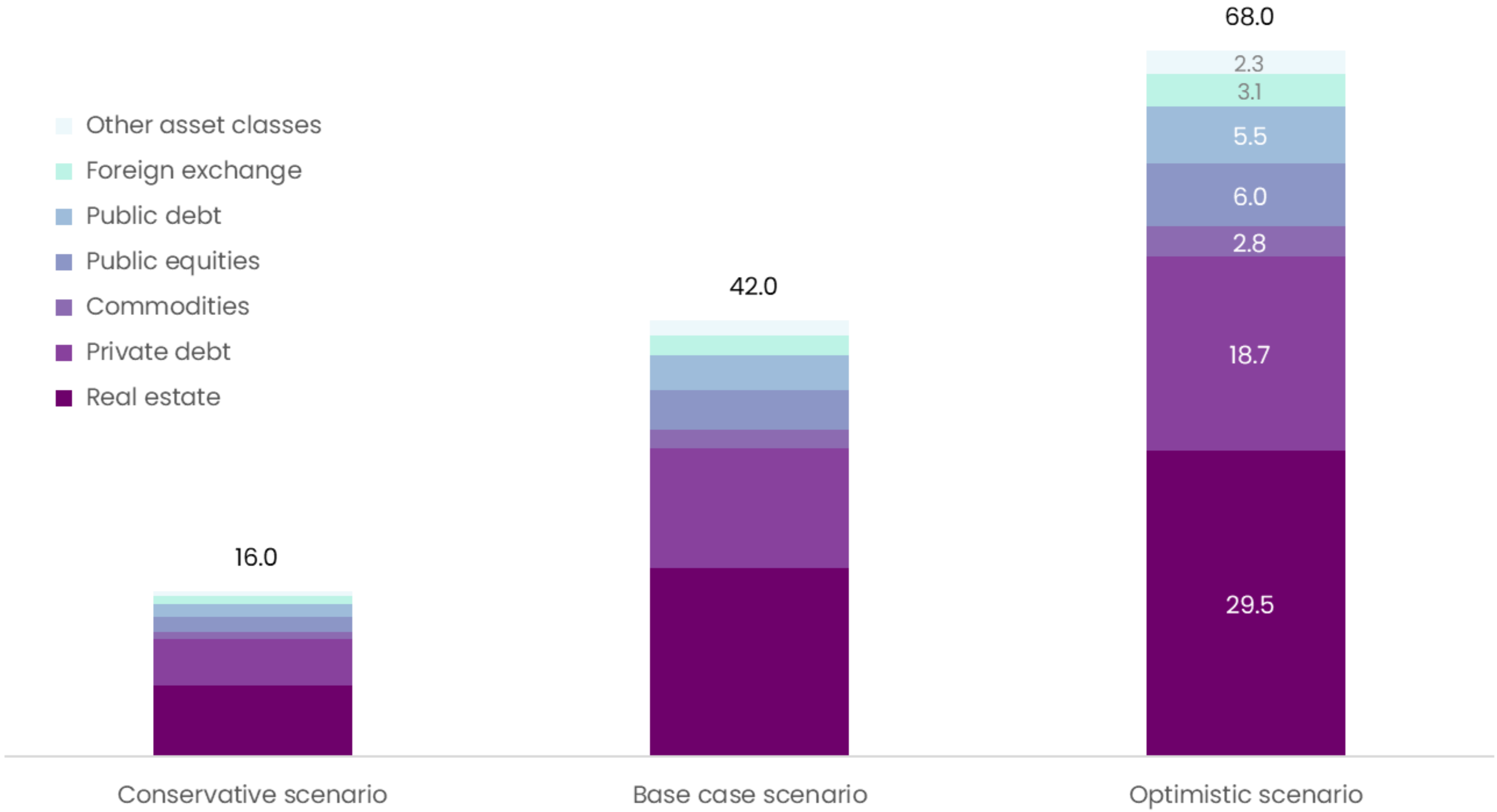
Appendix A
Tokenization platforms and protocols.
This table alphabetically reports 135 platforms and protocols that currently tokenize real-world assets including number ("n"), name ("*Platform/Protocol*"), and the type of asset class they tokenize ("*Tokenized Asset Class*").

n	Platform/Protocol	Tokenized Asset Class	n	Platform/Protocol	Tokenized Asset Class
1	Aconomy	Physical Assets	69	INX	Private Credit, Private Equity
2	ADDX	Private Equity, Real Estate, Investment Funds, Physical Assets, Private Credit, Fixed Income, Fiat / FX	70	KlimaDAO	Carbon Credits
3	Aktionariat	Private Equity	71	LandX	Commodities, Real Estate, OTC Derivatives
4	AllianceBlock	Private Equity, Public Equity	72	Liquid Mortgage	Real Estate, Private Credit
5	Alphaledger	Fixed Income	73	Maker DAO	Fiat / FX
6	Alta	Real Estate	74	Maple	Fixed Income, Private Credit
7	AmFi	Private Credit	75	Matrixdock	Fixed Income
8	Anzen	Private Credit	76	Maxos	Fixed Income
9	Arca Labs	Fixed Income	77	Meld Gold	Commodities
10	Archblock	Fixed Income, Real Estate, Private Credit	78	Mercado Bitcoin	Private Credit, Fixed Income
11	Arf	Private Credit	79	Mountain Protocol	Fiat / FX
12	Atlendis	Fixed Income, Private Credit	80	Nyala	Private Credit, Real Estate, Investment Funds, Carbon Credits
13	Aurus	Commodities	81	Obligate	Private Credit
14	Backed Finance	Public Equity, Private Equity, Private Credit, Fixed Income	82	Ondo	Fixed Income
15	Bitbond	Private Credit	83	Open Eden	Fixed Income
16	Black Manta Capital Partners	Commodities, Investment Funds, Private Equity	84	OpenChrono	Physical Assets
17	BlockCellar	Physical Assets	85	Opium	OTC Derivatives
18	Blocksquare	Real Estate	86	Ownera	Private Equity, Real Estate, Fixed Income
19	Bluejay Finance	Private Credit	87	Parabol	Fixed Income
20	Bondblox	Private Credit, Fixed Income	88	Parcl	Real Estate
21	Brale	Fiat / FX	89	Paxos	Commodities
22	Breaker	Data	90	PeerHive	Private Credit
23	Brickken	Real Estate	91	Petale	Commodities,Private Credit,Real Estate,Private Equity,Physical Assets
24	Brightvine	Real Estate	92	Polymath	Real Estate, Private Equity

n	Platform/Protocol	Tokenized Asset Class	n	Platform/Protocol	Tokenized Asset Class
25	Bru Finance	Private Credit	93	Polymesh	Real Estate, Physical Assets, Data
26	BSOS	Private Credit	94	Polytrade Finance	Private Credit
27	Cashlink	Real Estate, Investment Funds	95	Pontoro	Private Credit, Infrastructure
28	CellarDAO	Physical Assets	96	Propy	Real Estate
29	Centrifuge	Private Credit, Fixed Income	97	PV01	Private Credit, Fixed Income
30	Cerchia	Data	98	RealT Tokens	Real Estate
31	Circle	Private Credit, Fixed Income, Fiat / FX	99	Ribbon Lend	Private Credit
32	CitaDAO	Real Estate	100	Robinland	Real Estate, Private Credit
33	Clearpool	Private Credit	101	Rooba Finance	Real Estate, Private Credit, Private Equity, Commodities
34	CODEX	Physical Assets	102	Sapling	Private Credit
35	Cogito Protocol	Private Credit, Fixed Income	103	Securitize	Private Equity, Investment Funds
36	Credefi	Private Credit	104	Securrency	Public Equity, Private Equity
37	Credix	Private Credit	105	Spydra	Multi-use
38	dclex	Public Equity	106	Stable	Fixed Income
39	Defactor	Private Credit	107	Stasis	Fiat / FX
40	Dexstar	Private Credit	108	Stokr	Public Equity
41	DigiShare	Real Estate	109	Superstate	Fixed Income
42	eNor Securities	Commodities, Private Credit, Private equity, Real Estate	110	Swarm	Public Equity, Fixed Income, Private Equity
43	Ensuro	Data	111	Synthetix	OTC Derivatives
44	Estate Protocol	Real Estate	112	Tangible	Commodities, Real Estate
45	Fabrica	Real Estate	113	Tassets	Private Credit, Private Equity, Real Estate, Carbon Credits
46	Fireblocks	Public Equity, Private Equity, Carbon Credits, Fiat / FX	114	Taurus	Multi-use
47	First Digital Labs	Fiat / FX	115	Tether	Fiat / FX
48	Florence Finance	Private Credit	116	Texture Capital	Private Equity, Private Credit
49	Flowcarbon	Carbon Credits	117	Token City	Real Estate
50	Fnality	Fiat / FX, Fiat / FX	118	Token Forge	Real Estate, Private Equity, Private Credit
51	Forge SG	Fiat / FX, Private Credit, Private Equity	119	Tokenize.it	Private Equity
52	Fortunafi	Private Credit, Fixed Income, Fiat / FX	120	Tokeny	Real Estate, Private Equity, Investment Funds, Private Credit
53	Franklin Templeton Benji Investments	Public Equity, Fixed Income	121	Toucan	Carbon Credits
54	Frictionless	Investment Funds	122	Tribal Finance	Private Credit
55	Frigg	Private Credit	123	T-Rize	Real Estate, Private Equity, Private Credit

n	Platform/Protocol	Tokenized Asset Class	n	Platform/Protocol	Tokenized Asset Class
56	Fusang	Private Credit, Private Equity, Investment Funds	124	TrueFi	Private Credit
57	Gemini	Fiat / FX	125	Trustfx	Fiat / FX
58	Goldfinch	Private Credit, Fiat / FX	126	UMA	OTC Derivatives
59	Groma	Real Estate	127	Unikura	Physical Assets
60	Hamsa Pay	Private Credit	128	Untangled	Private Credit
61	Hashnote	Fixed Income	129	Vertalo	Private Equity, Public Equity
62	HomeCoin	Real Estate	130	Villcaso	Real Estate
63	HoneyBricks	Real Estate	131	Voltz	OTC Derivatives
64	Huma	Private Credit	132	Wisdomtree Prime	Public Equity, Investment Funds, Fixed Income
65	Impact Market	Private Credit	133	Yieldteq	Private Credit, Fixed Income
66	Intain	Private Credit	134	Zivoe	Private Credit
67	Inveniam	Physical Assets	135	Zodor	Commodities, Private Credit, Private Equity, Real Estate
68	InvestaX	Private Credit, Investment Funds			

Appendix B
Tokenized fraction scenarios.
This figure reports three tokenization scenarios: (1) conservative scenario, (2) base case scenario, and (3) optimistic scenario. We estimate that real estate and private debt are the two most tokenized asset classes by 2030 in the optimistic scenario, with tokenized values of $29.5 trillion and $18.7 trillion, respectively. All values are reported in trillions of dollars.



Appendix C

Efficiency gains and savings per dollar tokenized.

This figure reports the efficiency gains in billions of dollars per annum and savings per dollar tokenized (G_i) for each of the ten asset classes. The efficiency gains are plotted with the bars using the left-hand-side axis and the savings per dollars tokenized are plotted with the solid line using the right-hand-side axis. The largest savings per dollar tokenized are in foreign exchange, carbon credits, investment funds, and OTC derivatives asset classes while in in dollar terms, the largest efficiency gains are for FX, public debt, and private debt asset classes.