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Tokenization of Real-World Assets: Legal Frameworks, Market Dynamics, and Policy Pathways for a Decentralized Financial Future

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Abstract:

This paper examines how blockchain-based tokenization has revolutionized real-world assets (RWAs), with a focus on fixed-income securities like bonds. In financial markets, tokenization - the process of transforming physical asset ownership rights into digital tokens on a blockchain - has become a game-changing innovation that promises improved accessibility, liquidity, and transparency. Examining tokenization mechanisms, the paper shows how distributed ledger technology and smart contracts simplify processes, shorten settlement times, and lessen the need for middlemen.

The paper demonstrates the usefulness and advantages of tokenized bonds by analysing recent case studies, such as the European Investment Bank's the issuance of digital bonds and BlackRock's introduction of its first tokenized fund on the Ethereum blockchain. Additionally, it looks at how regulations are changing, addressing programs like the Markets in Crypto-Assets (MiCA) regulation of the European Union, which aims to give digital assets a comprehensive framework. In addition, the paper examines the difficulties in implementing tokenization, including issues with legal recognition and technological compatibility, and assesses possible advancements in this field in the future. This paper adds to a better understanding of how blockchain technology is changing conventional financial instruments and markets by offering a thorough assessment of the state and prospects of asset tokenization today.

Keywords: tokenized bonds, real-world assets, blockchain-based securities, smart contracts, digital asset regulation.

JEL Classification: G15; G23; O16; K22.

Introduction

The global financial industry is beginning to recognize that distributed ledger technology (DLT) and blockchain technology have the potential to completely transform conventional financial operations (Bank for International Settlements [BIS], 2024; Financial Stability Board [FSB], 2023). Tokenized bonds, or conventional bonds issued as digital tokens on blockchain networks, are among the most exciting applications of blockchain technology. Some potential advantages of such bonds include increased accessibility, reduced operating and transaction costs, significantly shorter settlement times, and higher transaction efficiency (Channing, 2024), particularly for retail investors who frequently face challenges in traditional financial markets (Goldman Sachs, 2021; OECD, 2020).

However, there are still problems, like the need for a robust technological infrastructure and unclear regulations. In an effort to balance investor protection and innovation, international regulatory bodies are working to develop frameworks for regulating digital assets.

This paper examines in detail the evolution of tokenized bonds from early pilot projects to their potential mainstream integration. It looks at how regulations are changing in various jurisdictions, conducts an empirical analysis of market trends and adoption, evaluates the financial and economic impacts of general tokenization, and pinpoints major adoption obstacles. Finally, it provides evidence-based policy recommendations aimed at accelerating tokenized bonds' successful integration into global financial markets.

1. Literature Review

Numerous studies have shown that tokenization can revolutionize financial markets by increasing operational efficiency, democratizing access to investments, and improving liquidity (Boston Consulting Group, 2022; Chainlink Labs, 2025; OECD, 2020). Numerous studies show how blockchain technology benefits the securities markets, emphasizing significant gains in efficiency, particularly in transaction settlement, reduced reliance on middlemen, and increased market transparency (Garcia Ocampo et al., 2023; Nishith Desai Associates, 2025). Tokenization has been shown to lower entry barriers for smaller investors, enabling greater market liquidity and broader market participation (Izadin & Yusof, 2024). Scholars who have extensively researched the democratizing effects of tokenization have noted that fractional ownership provides retail investors with unprecedented access to historically exclusive financial assets such as bonds and real estate (Chan, 2024; OECD, 2020). This inclusivity not only expands the pool of possible investors but also has the potential to stabilize markets by promoting more diverse investor participation and deepening the market (ADB, 2024). Many problems and challenges still exist, though, particularly in the regulatory domains. Scholars and policy analysts frequently point to regulatory ambiguity and fragmented international frameworks as the main barriers to the growth of tokenized financial instruments (Nextrope, 2023; Garcia Ocampo et al., 2023). Studies have shown that different regulatory requirements across jurisdictions can restrict global scalability and adoption rates by creating uncertainty and complexity for investors and multinational issuers (FSB, 2023; OECD, 2020).

Technological interoperability also appears as a critical issue in the literature. Experts warn that without universal standards, tokenized assets may become isolated in siloed platforms, potentially undermining the potential liquidity and efficiency benefits of tokenization (Polymath Network, n.d.; Tokeny, 2023). It has been suggested that standardized protocols like CCIP and ERC-1400 guarantee technical interoperability in order to fully realize the advantages of tokenized securities, including bonds (Chainlink Labs, 2025).

The literature looks closely at the security risks associated with tokenized securities and blockchain. Among the problems are cybersecurity threats, vulnerabilities in smart contracts, and the broader consequences of technical failures (Nishith Desai Associates, 2025; Tokeny, 2023). Researchers emphasize the need for stringent cybersecurity laws and frequent audits of blockchain platforms in order to lower these risks and protect investor assets (Garcia Ocampo et al., 2023). Empirical research consistently supports the notion that tokenization significantly reduces the cost of issuing and trading securities, primarily due to its ability to improve settlement procedures and eliminate the need for middlemen (ECB Statistical Warehouse, 2024; World Bank Open Data, 2024). These efficiency improvements lead to significant cost savings, particularly for smaller issuers and investors, further democratizing access to financial markets (Izadin & Yusof, 2024). However, empirical research suggests that tokenization may pose unique systemic risks. The rapid and widespread adoption of tokenized assets without adequate regulatory oversight, according to researchers, could exacerbate financial stability risks and lead to market fragmentation and increased volatility (BIS, 2024; FSB, 2023). The literature also identifies potential operational risks, such as an increased reliance on digital infrastructure, which, if compromised, could hinder market functioning (Chainlink Labs, 2025).

The regulatory literature goes into great detail about the need for unified international standards. Scholars argue that international cooperation and regulatory framework harmonization are crucial to reducing jurisdictional fragmentation, streamlining compliance, and facilitating cross-border tokenized bond transactions (OECD, 2020; Nextrope, 2023). Furthermore, studies point to promising frameworks that allow experimentation while providing sufficient investor protection, such as the EU's DLT Pilot Regime (FSB, 2023; Goldman Sachs, 2021). Tokenization's long-term macroeconomic effects, such as its impact on investor behaviour, financial stability, and overall economic dynamics, have been the subject of numerous studies, but comprehensive empirical assessments are still conspicuously lacking. Researchers emphasize the importance of closing this gap through rigorous economic modelling and comprehensive longitudinal studies in order to adequately inform policy decisions (BIS, 2024; ECB, 2024).

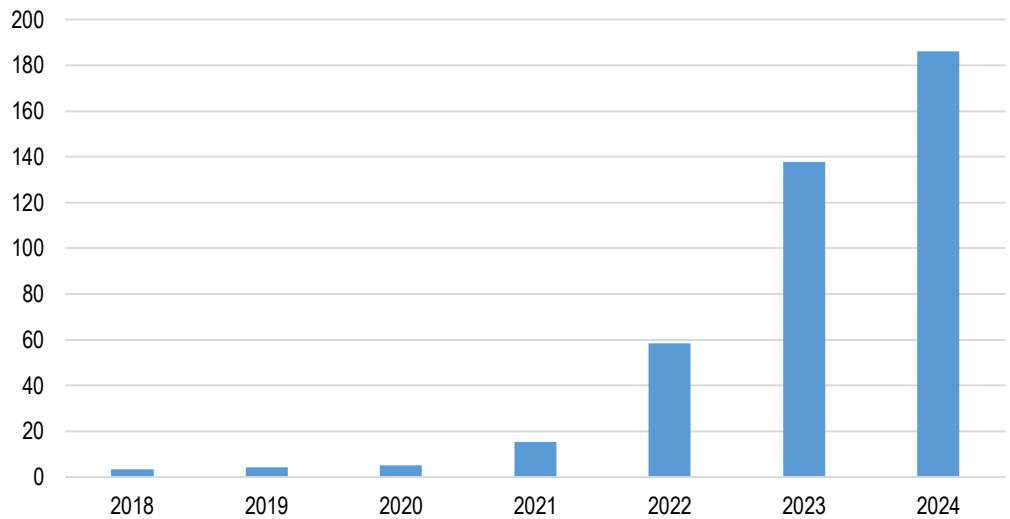
In conclusion, tokenized bonds are generally considered in the literature to be a revolutionary innovation that could drastically change financial markets. To fully achieve the potential benefits of tokenization, however, significant systemic, technological, and regulatory barriers remain, necessitating further research, global cooperation, and targeted legislative measures.

2. Empirical Analysis of Market Size, Issuance, and Trends

2.1. Global Market Overview (2018 - 2024)

It is anticipated that the market for tokenized real-world assets (RWAs) will have expanded from nearly nothing in 2018 to 186 bil. USD by the middle of 2024 (Oyebanji, 2024; Tokenized Asset Coalition, 2024). As seen in Figure 1, the total market capitalization - which includes both on-chain fiat-backed tokens and other asset classes - rose by roughly 32% annually (Ledger Insights, 2024). Importantly, over 90% of the total value of tokenized assets as of 2024 is made up of stablecoins, or blockchain tokens based on fiat currencies (Liu, 2024; Federal Reserve Board, 2024).

Figure 1. Total tokenized asset market size, 2018 - 2024 (bil. USD)



Note: The market grew from under 5 bil. USD in 2018 - 2019 to over 180 bil. USD by 2024, driven predominantly by fiat-backed stablecoins (Tokenized Asset Coalition, 2024; RWA.xyz, 2024). Excluding stablecoins, the RWA sector was approximately 15 bil. USD in 2024 (Investax, 2024).

Data source: rwa.xyz data; Tokenized Asset Coalition (2024); Blockworks (Liu, 2024).

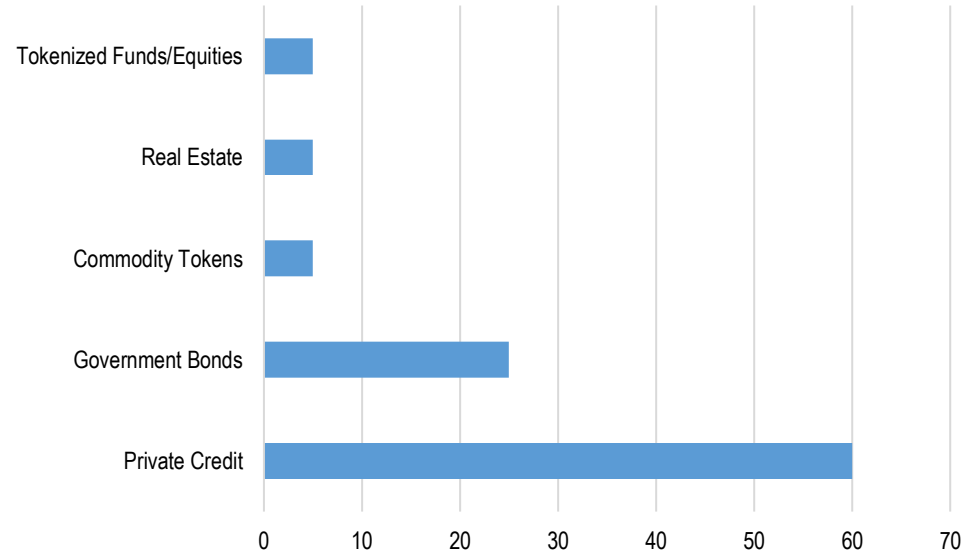
In early 2020, there were only roughly 4-5 bil. USD worth of USD-pegged stablecoins available overall; by 2022, that amount had increased to over 150 bil. USD (Tether Ltd., 2023). Despite a brief contraction during the 2022 crypto downturn, the stablecoin industry showed resilience (McKinsey & Company, 2023). The combined market capitalization of USD stablecoins, led by USDT and USDC, approached 130 bil. USD by the end of 2023

as investor demand grew in 2024 (OECD, 2020). With a market value of between 150 and 200 bil. USD, stablecoins made up over 90% of the tokenized asset ecosystem in 2024 (Tokenized Asset Coalition, 2024; BIS, 2024). Fiat-backed stablecoins have essentially become the most prevalent use case for tokenization, serving as settlement currency and facilitating on-chain liquidity (Liu, 2024; Deloitte, 2023; Tokenized Asset Coalition, 2024).

With an on-chain value of around 15.2 bil. USD as of December 2024 (Tran, 2024; McKinsey & Company, 2023), the market for tokenized assets, or ex-stablecoins, is fast increasing but still smaller than stablecoins. This market segment consists of tokenized securities, funds, real estate, commodities, and other assets; occasionally, this more limited definition refers to "real-world assets". Even without stable coins, the RWA sector grew by over 85% in 2024 (Nethermind & PwC, 2025; Tokenized Asset Coalition, 2024).

Figure 2 shows that private credit (loans and receivables) and tokenized government bonds (treasuries) comprised the two largest elements of this non-stablecoin group in 2023 - 2024. Next followed smaller categories including equities funds and real estate as well as commodities-backed tokens - mostly gold - BlackRock, 2023; Deloitte, 2024. Specifically, by value, on-chain private credit - including real estate loans, trade finance pools, and other debt - accounted for between 60 and 65 percent of the non-stablecoin RWA market in late 2024 (MakerDAO, 2023; Coy & Bhargava, 2023).

Figure 2. Composition of the tokenized RWA market (excluding stable coins) (%) in 2024



Note: Private credit (tokenized loans and receivables) and on-chain government bonds together account for approximately 80 - 85% of non-stablecoin RWAs by value (Investax, 2024). Commodity-backed tokens (e.g., gold) and other assets (real estate, tokenized funds/equities) comprise the remainder.

Data source: Investax (2024) (investax.io)

Tokenized government debt - particularly US. Treasury bills on-chain as digital securities - grew quickly and by approximately 600% in 2023 alone (CoinDesk, 2023; Federal Reserve Board, 2024). More than 20 financial institutions were offering tokenized US. Treasury products by early 2024 as the overall on-chain treasury market exceeded 0.9 bil. USD by late 2023 and reaches 4+ bil. USD by early 2025 (Ledger Insights, 2024; Investax Capital, 2025). Comprising mostly digital gold (Tether Ltd., 2023; Openware, 2024), with a total market value of over 1 bil. USD in 2024, over 5% of the RWA market consists of commodities-backed tokens. Tokenized real estate and equity funds - both of which right now own far below 10% of the market - are expected to expand as additional projects go online (Johnson, Larion, & Tuths, 2022; Zhou et al., 2023). One industry analysis estimates that by 2024 there will be over 150 different RWA token issuers and platforms globally, spanning a range of asset classes (Oyebanji, 2024; Tokenized Asset Coalition, 2024).

2.2. Regional Market Dynamics

Regional differences in asset tokenization adoption can be attributed to market readiness and regulatory frameworks (Aldasoro et al., 2023; Garcia Ocampo et al., 2023). Under pre-existing securities exemptions, there were a lot of security token offerings (STOs) in North America (US) in 2017 - 2019. Using SEC Reg D or Reg S private placements, more than 400 mil. USD was raised through STOs worldwide in 2018; many of these were by US companies (e.g., Spice VC's tokenized fund in 2018; Johnson, Larion, & Tuths, 2022; Spice VC, 2018). However, during that time, US regulators did not implement custom tokenization frameworks, which limited the liquidity of these tokens for public trading (Tosato, Dick, & Odinet, 2025; Garrido, 2023). Because of its dominance in stablecoins and private markets, the United States continues to play a significant role in shaping the RWA space despite regulatory uncertainty. US Treasuries are the foundation of the on-chain bond market, and prominent USD stablecoins are issued by American companies (such as Circle's USDC). Tokenized US Treasury bills became a popular yield product globally in 2023 as US interest rates rose. Together, US-based fintechs (like Franklin Templeton, WisdomTree, and Hashnote) and DeFi protocols (like Ondo Finance and MakerDAO) brought nearly 1 bil. USD worth of T-bills to the blockchain (MakerDAO, 2023; Franklin Templeton, 2023). More than 80% of all Treasury tokens on the blockchain by the end of 2023 were linked to US government debt (Ledger Insights, 2024; CoinDesk, 2023).

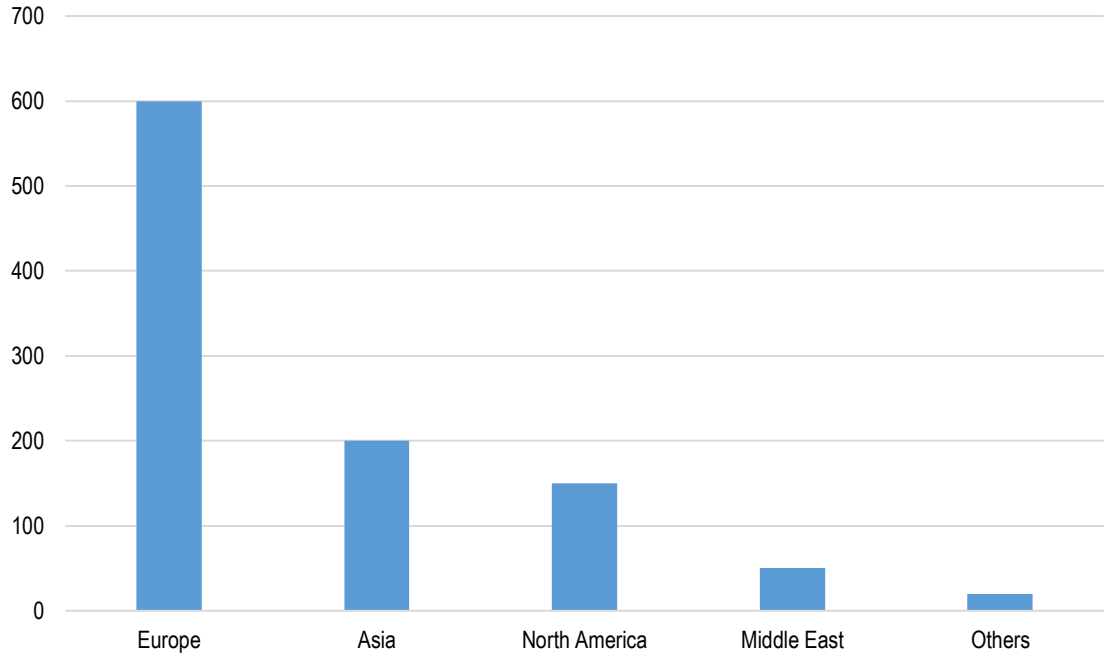
Prominent American financial institutions also started adopting tokenization. For instance, BlackRock introduced a tokenized fund (BUIDL) in 2024 in collaboration with Coinbase and Securitize (BlackRock, 2023; Investax Capital, 2025), and JPMorgan created its Onyx platform to tokenize money market fund shares and collateralize trades (Lobban, 2022). Despite this, the US public markets are still wary because the SEC has taken a conservative stance and no US corporate or sovereign bond has been issued natively on a public blockchain as of yet. US regulators were still investigating the implications of tokenization as of December 2024. A Congressional report noted that there were approximately 225 bil. USD in tokenized "securities" outstanding, mostly stablecoins and tokenized funds, and called for more precise legal definitions (US Congressional Research Service, 2024; Uyeda, 2025).

In terms of regulated tokenized securities, Europe (EU and UK) has taken the lead. Figure 3 provides a broad summary of the total value of the world's largest tokenized bond issuances. Under favourable regulatory environments, a number of well-known digital bond issuances have occurred in Europe. A historic public blockchain bond issue by a supranational organization was the European Investment Bank's 100 mil. EUR two-year digital bond in April 2021, which was issued on Ethereum and settled in experimental form using CBDC (European Investment Bank, 2021; Ledger Insights, 2024). In 2022, a 100 mil. EUR EIB bond was issued on a private DLT platform (Goldman Sachs' GS DAP) (Ledger Insights, 2022; World Bank, 2024). In mid-2021, Germany enacted the Electronic Securities Act (eWpG), which recognized blockchain-based bonds legally. Corporate issuers quickly began to capitalize on this. Under the eWpG framework, Siemens AG, for example, first issued a 60 mil. EUR digital bond in 2023 and then expanded with a 300 mil. EUR tokenized bond issuance in 2024 (Siemens AG, 2024). In November 2022, UBS issued a 375 mil. CHF digital bond on Switzerland's SIX Digital Exchange (SDX), which was established in 2021 as a fully regulated DLT market infrastructure. At that time, it was the largest native digital bond in the world (UBS AG, 2022; Reuters, 2022).

Europe far outpaced other regions in tokenized bond issuance, with a total of over 0.5 - 0.6 bil. USD issued by 2023 (mainly in Switzerland, Germany, and France) (Ledger Insights, 2024). The EU DLT Pilot Regime (2023), which permits markets to trade tokenized securities in a sandbox setting, is another example of how European regulators have permitted experimentation (ESMA, 2023; Better Finance, 2023). The Eurosystem conducted DLT settlement trials totalling 532 mil. EUR across 50+ transactions with commercial banks between May and September 2024, even facilitating the first euro-area sovereign bond issuance on DLT. The European Central Bank has been actively investigating tokenization for bond markets. Europe's dedication to incorporating blockchain technology into traditional finance is demonstrated by these trials. By 2024, DLT bond pilots or studies had been

carried out by almost all of Europe's major stock exchanges and central banks, including the Deutsche Börse and the Banque de France (ICMA, 2024; Tokenized Asset Coalition, 2024). Europe is a leading region in this field, alongside the United States, with an estimated 40 - 50% of non-stablecoin RWA value (Tokenized Asset Coalition, 2024; Deloitte, 2024).

Figure 3. Cumulative value of major tokenized bond issuances by region (2018 - 2024) (mil. USD)



Note: Europe leads due to multiple large digital bonds by institutions such as the European Investment Bank (EIB) and UBS, totalling over 600 mil. USD (EIB, 2021; UBS, 2022; Ledger Insights, 2024). Asia follows with approximately 200 mil. USD, including Hong Kong's 100 mil. USD tokenized green bond (CoinDesk, 2023; HKMA, 2023). North America and other regions have seen limited issuance so far.

Data sources: Press releases and industry reports (EIB, 2021; Ledger Insights, 2024; UBS, 2022).

Due to government initiatives in financial centers like Singapore, Hong Kong, and Australia, RWA tokenization has also exploded in the Asia-Pacific region. Through Project Guardian, run by the Monetary Authority of Singapore, Singapore in particular has encouraged institutional DeFi pilots (MAS, 2022; Ledger Insights, 2022). Using a modified Aave protocol, Project Guardian's initial pilot in 2022 allowed tokenization of government bonds and foreign exchange for on-chain trading between DBS Bank, JPMorgan, and SBI (Ledger Insights, 2022; UBS AG, 2022). Using compliant "permissioned DeFi" pools, this successful test showed that tokenized Singaporean government securities and Japanese government bonds could be settled atomically on a public blockchain (Polygon) (MAS, 2022; GFMA & BCG, 2023). Additionally, Singapore is home to authorized security token exchanges such as ADDX and 1exchange, which list tokenized bonds, real estate trusts, and private equity funds. For instance, Hamilton Lane tokenized a private assets fund worth over 2 bil. USD on ADDX in 2022 to provide Asian investors with fractional access (at a minimum of 10,000 USD as opposed to the customary 125k USD) (Hamilton Lane, 2022).

Hong Kong has also taken aggressive action. In February 2023, the Hong Kong government issued the first tokenized government bond by a sovereign in history, 800 mil. HKD (101 mil. USD) tokenized green bond (Hong Kong Monetary Authority, 2023; CoinDesk, 2023). HSBC, BoC, and Crédit Agricole were partners in the fully issued one-year green bond (with a coupon of 4.05%) on a permissioned blockchain platform. Digital lifecycle events, such as the coupon and redemption, were managed (CoinDesk, 2023; ICMA, 2024). Due to its success, Hong Kong's monetary authority (HKMA) announced additional support for tokenized issuances, including issuer subsidies (HKMA, 2024; Cointelegraph, 2023). Mainland China has also started to participate: in 2023, the Bank of China

(BOCI) issued a 200 mil. CNH tokenized note in Hong Kong, the first tokenized security by a Chinese bank, and in 2021, the People's Bank of China oversaw a pilot program in which BSN and CCB issued digital infrastructure bonds (ICMA, 2024; World Economic Forum, 2023).

Other Asian countries are doing the same: Mitsui and SBI experimented with tokenized stock and real estate products after Japan changed its Fund Settlement Law in 2022 to permit security tokens (JFSA, 2022; Garcia Ocampo et al., 2023). In 2020, Thailand's central bank issued 50 bil. THB (1.6 bil. USD) in blockchain-based government savings bonds to individual investors after implementing a blockchain platform for such bonds (Wichit, 2020). Through the ASX's Synfini DLT platform and several state government bond pilots, including Queensland's blockchain bond in 2020, Australia (location of the World Bank's 2018 bond-i) keeps innovating (World Bank, 2018; World Bank, 2024). In Asia, there is increasing regulatory support for security tokenization. Hong Kong and Singapore have released official policy statements supporting the practice (MAS, 2023; Hong Kong Government, 2022), and the Middle East is not far behind. For instance, Dubai's VARA oversees security tokens, and Abu Dhabi's ADGM has developed a token framework (VARA, 2022; Bird & Bird, 2025).

By 2024, Asia's on-chain RWA volumes (not including stablecoins) were still only a few hundred million USD, but with strong government support, the region is predicted to grow quickly (Mitrade, 2024; Zawya, 2023). For example, by mid-2023, more than 10 bil. USD in bond volume had been tokenized globally, with the majority of that volume occurring in Asia and Europe, according to Hong Kong's HKMA (Hong Kong Monetary Authority, 2024; Ledger Insights, 2024).

2.3 Asset Class Trends and Notable Issuances

There are several asset classes involved in the tokenization movement, and their adoption paths vary.

Money Market Tokens and Fiat Currency

As mentioned, the largest RWA category is by far fiat-pegged stablecoins (USD, EUR, etc.). Furthermore, tokenized money market funds have become a link between DeFi and TradFi. With its share tokens settling on Stellar and Ethereum, Franklin Templeton's OnChain US Government Money Fund (OIN), for instance, began operations in 2019 and expanded to over 270 mil. USD assets under management by 2023 (Franklin Templeton, 2023).

Launched in March 2024, BlackRock's BUIDL fund tokenizes an Ethereum-based technology equity fund and has amassed over USD 650 mil. in just a few weeks (Tokenized Asset Coalition, 2024; Investax Capital, 2025). These show how tokens for fund shares are increasingly being used by institutions. In 2023, the Federal Reserve estimated that there were more than 200 mil. USD worth of tokenized securities (bonds, money funds, and exchange-traded funds) on public blockchains at that time (Federal Reserve Board, 2023). Industry experts predict that other tokenized "cash equivalents" (such as money funds, bank deposits, and even central bank digital currencies) will gain traction, potentially diversifying the fiat token space, even though stablecoins currently dominate in terms of liquidity and usage (World Economic Forum, 2023; Mastercard, 2024; Corker, 2023).

Corporate and Government Bonds

Since 2018, there have been significant pilot issuances of tokenized debt instruments, demonstrating the viability of DLT-based bond markets. The first significant tokenized bond, worth 80 mil. USD, was issued by the World Bank in August 2018 and operated on a private Ethereum network in Australia (World Bank Press, 2018). Subnationals such as the World Bank have since made a comeback, issuing a 100 mil. USD blockchain bond on Euroclear's DLT in 2022 and a 200 mil. CHF bond in 2024 that settles in SNB digital currency (World Bank, 2024). Municipal issuers like Lugano, Switzerland, which issued three rounds of digital city bonds via SDX from 2022 - 2024 totalling 250 mil. CHF, and sovereigns like Hong Kong (2023) have joined in (Ledger Insights, 2024). In 2019, financial institutions like Société Générale issued 40 mil. EUR worth of covered bond tokens, and in 2021, MakerDAO bought a 100 mil. EUR tokenized bond (Sandner et al., 2021). Under different regimes, corporations

such as Siemens, Volkswagen, Toyota, and UBS have issued pilot digital bonds (UBS AG, 2022; Siemens AG, 2024). It is evident that the number of tokenized bonds issued has increased. According to a 2024 International Capital Market Association report, "the volume of tokenized bond issuances is on the rise" (ICMA, 2024), and more conventional issuers are joining the market annually. An estimated 1-2 bil. USD in total bond value had been tokenized worldwide by the end of 2023 (CoinDesk, 2025; Sandor, 2024). According to projections, the tokenized bond market could increase 30 times by 2030, reaching over 300 bil. USD (Cointelegraph, 2023), albeit under rosy assumptions. These early issuances show efficiency gains like T+0 settlement, programmable coupons, and 24/7 trading, but they are still small in comparison to the 100 trillion USD conventional bond market (Deloitte, 2024; BIS, 2024). Table 2 (Section 4.4) also provides a brief summary of the main tokenized debt pilot issuances.

They also highlight ongoing limitations: the majority of tokenized bonds to date are either dual-listed with traditional custody or natively digital but still permissioned networks, as fully public, freely tradable security tokens are still constrained by regulatory compliance requirements (OECD, 2020; Federal Reserve Board, 2023).

Real Estate

Although the tokenization of real estate assets has drawn a lot of interest, the market size is still small. Early initiatives in 2018 - 2019 tokenized individual luxury properties; for example, the St. Regis Aspen resort sold 18 mil. USD of equity to accredited investors in 2018 after tokenizing it using Reg D security tokens (Aspen Digital, 2018). In the United States, a number of startups (RealT, Lofty, etc.) currently fractionalize rental properties, though usually on a small scale (tens or hundreds of thousands of dollars per property). The majority of real estate tokens are currently held off-exchange or remain illiquid, according to a 2022 analysis that found the actively traded tokenized real estate market cap was only 25 mil. USD (Larion, 2022). However, private placement platforms have tokenized sizable portfolios. For example, RedSwan and tZERO enabled qualified investors to tokenize more than 300 mil. USD in commercial real estate (office buildings in Texas and New York) in 2020 (Forbes, 2020; Johnson et al., 2022). With BrickMark's 50 mil. CHF token offering, supported by Zurich real estate, Europe saw its first tokenized REIT on Ethereum in 2019 (World Economic Forum, 2020). Tokenized feeder funds or REIT-like tokens, like MG Properties' Real Estate Token in Dubai, were introduced by a number of real estate funds in Asia and the Middle East by 2023 (Blossom, 2022).

Real estate tokenization market forecasts are extremely optimistic: According to Deloitte (2024), "up to 4.0 trillion of real estate could be tokenized by 2035," and the Boston Consulting Group (BCG, 2022) projected that real estate and infrastructure tokens would total 1.5 trillion USD by 2030. Even though these projections might turn out to be overly optimistic, they support the idea that tokenization can allow fractional investment in a segment of the 300 trillion global real estate market. Tokenized real estate funds (private equity real estate) have become the "low-hanging fruit" in the real estate market. In 2022, for example, KKR tokenized a part of its 4 bil. USD. Real Estate Growth Fund on the Securitize platform, allowing investors with as little as 10,000 USD to participate (Forbes, 2022). Similarly, since 2021, a number of tokenized real estate funds, such as Mapletree's India Trust, have been listed on Singapore's ADDX. Without actually tokenizing real estate or buildings, which frequently have complicated legal titles, these funds offer exposure to property assets through tokens (Lavayssière, 2025). In general, real estate tokenization is still in its infancy; according to a global survey conducted in 2023, only 12% of real estate companies had undertaken any tokenization activity (Zhou et al., 2023; Mitrade, 2024). However, as legal and technological frameworks advance, real estate tokenization is seen as a high-potential area.

Gold and other Commodities

Gold has led the successful tokenization of precious metals. With tokenized gold, physical bullion stored in vaults can be easily fractionally owned and traded around-the-clock. By 2023, the combined market value of the two biggest gold tokens, PAX Gold (PAXG) and Tether Gold (XAUT), was close to 1 bil. USD (Investax Capital, 2025). This amounts to about 0.5% of all private gold holdings worldwide (CoinDesk, 2025). Launched by Paxos Trust in 2019, PAXG is responsible for the custody of London Good Delivery bars and as of 2024, owed roughly

529 mil. USD (Tokenized Asset Coalition, 2024). Launched in 2020, XAUT also increased to about 500 mil. USD. With daily liquidity in the tens of millions, these tokens are being used more and more as on-chain "digital gold" investments and are traded on major exchanges (Ledger Insights, 2024). Apart from gold, other commodities are also represented by tokens, such as SilverCoin, PlatinumCoin, and even experimental tokens for natural gas and oil, which are offered by platforms like CommDAO and Vakt, though these are still specialized (BIS, 2024; WEF, 2023). Uranium tokenization is one special example; in 2022, Uranium3o8, a startup, produced tokens backed by uranium stockpiles, though volumes are still modest (Tokenized Asset Coalition, 2024). Commodity tokens were worth slightly more than 1.1 bil. USD by the end of 2024, with 83% of them backed by gold (Investax Capital, 2025). As market share shifted toward higher-yielding RWAs and gold prices stayed flat, this asset class grew by about 5% in 2024, trailing other RWA segments (Tokenized Asset Coalition, 2024; RWA.xyz, 2024). However, as organizations like the London Metals Exchange and CME investigate blockchain-based warehouses and tokenized warrants, there is potential for broader commodity tokenization, encompassing energy, metals, and agricultural commodities (Ledger Insights, 2023). This could also apply to tokenized carbon credits, which by 2023 had tokenized several million tons of voluntary credits (for example, through the Toucan protocol). However, the voluntary carbon market's verification problems hindered scaling (IMF, 2023).

Private Equity and Investment Funds

As asset managers look to expand their investor base, private equity, venture capital, and other alternative investments are becoming more tokenized. Apart from the previously mentioned instances of Hamilton Lane and KKR, in 2022 Apollo Global tokenized a segment of a credit fund on the Provenance blockchain (Apollo, 2022), and in 2023 Partners Group investigated tokenizing a private debt fund (OECD, 2020). Strong demand for fund offerings ranging from pre-IPO stocks to whiskey barrels was reported by tokenization platforms such as Securitize and Tokeny. Securitize had tokenized more than 3.3 bil. USD in client assets by the end of 2023 (Ledger Insights, 2024). Notably, Goldman Sachs announced plans to develop a native tokenization platform for alternative assets (CoinDesk, 2025), and Franklin Templeton started providing tokenized feeder funds for its flagship private credit strategies in the fall of 2023 (Franklin Templeton, 2023).

A feeder structure is frequently used by tokenized funds, whereby a specific share class of a fund is digitized and offered for sale to qualified investors as tokens. This simplifies issuance, lowers administrative costs, and lowers minimum investments, but it may not necessarily allow for full public liquidity (Deloitte, 2024). Hamilton Lane (2023) asserts that smart contracts facilitate the automation of capital calls and distributions. There is a lot of interest in tokenization, according to industry surveys. In 2023, 86% of Fortune 500 executives agreed that it could improve liquidity in private markets and increase access to capital (WEF, 2023; HackerNoon, 2024). In 2024, there was a change in rhetoric: the CEO of BlackRock referred to tokenization as “the next generation for markets,” while the CEO of Franklin Templeton called it “securitization on steroids” (Tokenized Asset Coalition, 2024; McKinsey & Company, 2023). Real action followed these declarations, as numerous major asset managers introduced pilot programs. As a result, the fastest-growing RWA segment was tokenized private markets (credit, equity, and funds), which grew by 40% in 2024 alone (RWA.xyz, 2024). On-chain private credit exceeded 9.5 bil. USD by the end of 2024, and tokenized private equity funds were valued at 0.5 - 1 bil. USD (TAC, 2024).

2.3. Year-over-Year Growth and Outlook

Rising from a modest beginning between 2018 and 2023, the proof-of-concept and infrastructure build-out phase of RWA tokenization expanded rapidly. The main causes of the almost 50-fold increase in the tokenized market - from less than 5 bil. USD in 2018 to over 250 bil. USD by 2022 - were stablecoin acceptance and the DeFi explosion. With stablecoins excluded, RWAs rose from practically zero in 2018 to 8 bil. USD in 2023 and then quadrupled to over 15 bil. USD in 2024 (Investax Capital, 2025). Notwithstanding legislative developments such the DLT Pilot Regime and MiCA, substantial institutional engagement including the EIB began in 2021 and stalled in 2022 due to decreases in the bitcoin price. Often referred to as "the year of RWA," on-chain Treasury holdings

rose 700% (CoinDesk, 2023; Blockworks, 2024), private credit RWAs grew by over 60%, and stablecoin supply was restored in 2023. The tokenized market expanded by another 32% in 2024, therefore validating RWAs as a strong and developing asset class in spite of continuous global crypto stagnation.

The forecasts of the sector are generally positive. Tokenized illiquid assets might make up 16.1 trillion USD, or around 10% of the global GDP, according to Boston Consulting Group (2022). Indicating 50 - 80% yearly growth rates, ripple and BCG (2023) projected 18.9 trillion USD by 2033; Citigroup (2023) projected 4 - 5 trillion USD in tokenized securities (Citi GPS, 2023; Sandor, 2025). These audacious forecasts, supported by rising institutional interest and regulatory clarity, are built on the extension into debt, money, and real estate. Government bonds, money markets, and real estate are among the areas where efficiency, liquidity, and round-the-clock trading are valuable; tokenization is increasingly concentrated in these sectors as well (McKinsey & Company, 2023).

Tokenized securities are fast expanding, but as CBDCs develop stablecoin expansion is expected to stop off. Whereas private credit and real estate tokens surged by 40 - 50% a year (PwC & Crypto Valley, 2019; RWA.xyz, 2024), tokenized public debt almost tripled in 2024. Geographic variety is rising quickly. Though by 2024 Europe and Asia accounted for more than half of all new issuances, over 80% of tokenized value in 2018 - 2020 came from the US. Jurisdictions such Switzerland, Singapore, and the United Arab Emirates have become regional hotspots for tokenization (MAS, 2023; ICMA, 2024; PwC, 2023) thanks in part to their unique regulatory systems. Ultimately, as the RWA market developed from an experimental to a multi-hundred-billion-dollar ecosystem, it showed consistent double- and triple-digit increase. Stablecoins founded the basis for on-chain liquidity even as bonds, loans, and other RWAs grew in prominence. As institutions raise their involvement and secondary markets grow, RWAs stand to benefit a bigger share of the worldwide capital markets (BlackRock, 2023; Deloitte, 2024). Notwithstanding challenges, particularly in the areas of interoperability, investor protection, and governance, the data points to tokenization transforming world banking over the next decade (IOSCO, 2022; World Economic Forum, 2024).

3. Global Regulatory and Legal Frameworks for Tokenized Bonds

3.1. Tokenization in the Bond Market

One of the main targets for real-world asset tokenization is the bond market, which is a fundamental component of international finance. In contrast to conventional book-entry securities, tokenized bonds are debt instruments (such as government or corporate bonds) that are issued as digital tokens on a blockchain. With quicker settlement, fewer middlemen, and more distribution channels, this innovation seeks to increase efficiency. Since 2018, a number of well-known pilots have shown that the idea is feasible.

For instance, the European Investment Bank (EIB) issued 100 mil. EUR in digital bonds on public and private blockchain platforms in 2021 and 2022, and the World Bank issued a 110 mil. USD bond in 2018 called "bond-i" on a private Ethereum-based platform. As long as the legal foundations were in place to acknowledge blockchain-based records, these projects verified that investors could subscribe and settle bonds using distributed ledgers (BIS, 2024; OECD, 2020). Tokenization in fixed income is appealing because it can democratize access (fractional ownership of high-value bonds), shorten settlement times (from days to near-real-time), and cut bond issuance and trading costs (Chan, 2024; FSB, 2023). As a result, several governments and significant financial institutions have started experimenting with tokenized bonds, viewing these trials as a model for the bond markets of the future.

3.2. Regulatory and Legal Approaches Across Jurisdictions

Legal classification and securities laws

According to Garcia Ocampo, Branzoli, & Cusmano (2023), a tokenized bond is still essentially a bond and is therefore typically governed as a security under current frameworks. It is not the nature of the instrument that is innovative, but rather the issuance and settlement infrastructure. By extending traditional securities laws to tokenized bonds in order to protect investors and maintain market integrity, while making specific adjustments to accommodate distributed ledger technology, the majority of jurisdictions have adopted a tech-neutral strategy.

Tokenized bonds are treated very differently by regulators. Five representative jurisdictions' approaches to sandbox participation, infrastructure readiness, and the legal recognition of tokenized bonds are summarized and compared in Table 1. While France's PACTE law and Germany's eWpG Act offer national-level recognition, the EU's DLT Pilot Regime (Regulation 2022/858) is at the heart of recent developments. The SEC in the United States lacks a comprehensive federal framework, but it applies traditional securities laws to digital assets. With the SFC's DLT sandbox and MAS's Project Guardian, respectively, Singapore and Hong Kong have taken proactive measures. With its DLT Act and live trading platforms like SDX, Switzerland is a leader (FINMA, 2021; OECD, 2020).

Table 1: Regulatory comparison across jurisdictions

Jurisdiction	Legal Recognition of Tokenized Bonds	Pilot Regimes or Sandboxes	Market Infrastructure Status
European Union	▪ Recognized under MiFID II (esma.europa.eu), eWpG Act (loc.gov) ▪ MiCA (2023) covers crypto tokens; eIDAS amendment (2023) recognizes DLT records; DLT Pilot Regime in effect (2023) (esma.europa.eu)	▪ DLT Pilot Regime, multiple country sandboxes (e.g., AMH in Belgium)	▪ Partially integrated (Proof-of-concept stage; target linking to T2S)
United States	▪ Treated as securities by US Securities and Exchange Commission (SEC), typically requiring compliance with the Securities Act of 1933 (govinfo.gov) and the Exchange Act of 1934 (govinfo.gov)	▪ Federal tokenization symposiums; SEC/NASDAQ pilots of DLT securities	▪ Fragmented (Private solutions (JPM Coin, etc.); DTCC exploring DLT.)
Singapore	▪ MAS allows tokenized assets under existing laws (Payment Services Act, SFA); Project Guardian framework in place (tokenized bonds/funds) (cointelegraph.com). CBDC experiments ongoing	▪ Project Guardian (tokenized FI & funds frameworks) published, launch mid-2023 (cointelegraph.com). Regulatory approval for Singapore Exchange tokenized funds.	▪ Pilot-stage (SIMEX and CBDC test nets. MAS has digital asset APIs.)
UAE	▪ Virtual Assets Regulatory Authority (VARA, 2022) licenses crypto businesses and custodians (vara.ae)	▪ VARA Sandbox for asset tokenization; ADGM (Abu Dhabi) regulatory framework includes digital securities.	▪ Emerging (NASDAQ Dubai considering DLT for issuing sukuk.)
Switzerland	▪ DLT Act (2021): recognizes "ledger-based securities" on blockchain (cointelegraph.com); FINMA licenses DLT trading facilities and principals (notably SDX is live).	▪ FINMA DLT License ▪ Approvals granted to SDX (SIX Digital Exchange) as DLT trading facility and central securities depository.	▪ Fully licensed (SDX) ▪ SDX live for tokenized bonds/equities; federated with SIX exchange.

Note: *pilot* = regulatory sandbox or experimental program; integrated infra indicates national trading/settlement systems with DLT capabilities

Source: Compiled by author based on BIS (2024), FSB (2023), OECD (2020).

France changed its laws to specifically recognize blockchain-based securities registries, which allowed the EIB's 2021 digital bond to be issued under French law without any legal uncertainty regarding the validity of the ledger entries. Like all bonds, the bond complied with the EU Prospectus Regulation and disclosure requirements, with the exception of the way ownership was recorded and transfers were settled. In 2019, Societe Generale's digital assets division (Forge) also issued a 100 mil. EUR covered bond on Ethereum under France's DLT framework. Later, other instruments like a structured product and a stablecoin with a euro value were tokenized using the same crypto-friendly legal framework. These examples demonstrate the importance of having clearly defined legal foundations: tokenization cannot be widely adopted until laws explicitly declare that a DLT record confers an enforceable claim to the underlying asset (Garrido, 2023; Lavayssière, 2025). Researchers claim that the degree of this legal relationship between token and asset dictates the success of tokenization; market adoption will be limited if tokens are merely unofficial "digital twins" with no legal standing (Lavayssière, 5025). Global regulators have been updating laws and regulations to improve the legal status of tokenized securities. In order to address digital assets, the US Uniform Commercial Code was revised in 2022 to include the idea of "controllable electronic records" which can promote safe token transactions. According to academics, this modification provides a framework for real "debt tokens" in the context of business law (Tosato, Dick, & Odinet, 2025). Similarly, nations like Germany and Switzerland have enacted laws allowing electronic or ledger-based securities, granting tokenized bonds the same legal standing as paper or dematerialized bonds under standard law (FSB, 2023). Such legal reforms aim to ensure that ownership transfers made through blockchain are legally final and will protect token holders' rights (to payments, collateral, etc.) in the event of disputes or insolvency (Garrido, 2023).

Regulatory initiatives and sandboxes

In order to safely integrate tokenized bonds, regulators have set up sandboxes and pilot programs in addition to changing laws. The DLT Pilot Regime (Regulation EU 2022/858, effective 2023) in the EU allows authorized infrastructures to trade and settle tokenized instruments, like bonds, without requiring a central securities depository. This has made it easier to issue a variety of tokenized bonds, including Project Venus by the central bank of Luxembourg and Bank of France, and Iberdrola's blockchain-recorded green bond under Spain's sandbox.

Hong Kong issued 800 mil. HKD (100 mil. USD) in tokenized green bonds in 2023. Cost savings and T+1 settlement were achieved by this sovereign issuance, which was handled within a regulatory sandbox and settled via Goldman Sachs' DLT platform (Chan, 2024). Through Singapore's Project Guardian, which was launched by MAS in 2022, banks like DBS and JPMorgan can test tokenized bonds and deposits in a controlled environment (Garcia Ocampo et al., 2023). Similarly, the UAE created a Virtual Assets Regulatory Authority and revised its laws to license tokenized securities custodians and exchanges.

These initiatives demonstrate that regulators support tokenized bonds within frameworks that ensure compliance, disclosures, and market oversight. The Financial Stability Board notes a global trend to incorporate tokenized assets into existing regimes while promoting cross-border cooperation to prevent regulatory gaps (FSB, 2023). By 2025, tokenized bonds will be accepted by most major jurisdictions through pilot programs or revised laws that balance innovation and investor protections.

3.3. Technology and Market Infrastructure for Tokenized Bonds

Legal frameworks and technical architecture for tokenized bonds have evolved together. Early initiatives sought permissioned blockchains to guarantee privacy and compliance. For instance, BIS's Project Genesis created tokenized green bonds utilizing a closed ledger in Hong Kong, therefore allowing retail investment and on-chain ESG tracking. Growing in appeal as a means of improving openness and interoperability are public and hybrid blockchains. One significant example is the 2021 Ethereum-based digital bond the EIB issued, which was paid for using a digital euro from the Banque of France. By removing middlemen like paying agents, this experiment showed how smart contracts might automate significant bond tasks including coupon payments, transaction execution, and investor onboarding. These agreements also supported automated redemptions and corporate actions -

programmable features. Public blockchains generate privacy and compliance issues; but hybrid solutions combining public openness with permissioned layers or identity gating are starting to show up. Efforts to include compliance into open token standards (OECD, 2020; BIS, 2024) are shown by protocols such ERC-1400 and ERC-3643.

Settlement and custody

Unlike conventional bonds tracked by central securities depositories (CSDs), tokenized bonds can be settled peer-to--peer on-chain utilizing payment tokens or CBDCs for rapid delivery-versus-payment. Most institutions are not ready for self-custody, hence banks and fintechs act as guardians, token storage in safe wallets. Legal recognition is still challenging; some countries require a CSD for a lawful ownership transfer. Others' laws have been changed. For example, Switzerland's DLT Act (2021) gives native issuing of securities based on ledgers complete legal standing (e.g., SIX Digital Exchange), therefore allowing for native issuing of securities based upon ledgers without a CSD. On their books, some trustees or CSDs also maintain "omnibus" accounts showing little holdings.

Under the EU's DLT Pilot Regime, the CSD need is momentarily waived should DLT solutions satisfy legal criteria in order to encourage experimentation. Given this, legal systems are progressively changing to let blockchain ledgers take place of conventional record-keepers. Hybrid models - which combine old infrastructure with new digital frameworks - will be the most often used until then (Lavayssière, 2025).

Trading venues and liquidity

Tokenized bonds need for active secondary markets in addition to being issued and settled. The bulk is owned by long-term investors and has been issued thus far in pilots or private placements, thus little trading has emerged. Tokenized bonds must be traded on either new, controlled digital asset platforms or integrated into current exchanges if they are to offer liquidity. Special licenses for these kind of trading venues are made possible by the EU's DLT Pilot.

Rising adoption and the issuing and holding of more bonds on-chain will help secondary liquidity to improve. Authorities need these systems to offer the same level of security as traditional exchanges including investor protections (FSB, 2023), trade monitoring, and reporting.

Moreover, tokenization allows fractional ownership, hence lowering the entrance cost for individual investors. Tokenized bond markets let small investments (like 100 USD) unlike conventional bond markets, which have excluded people because of their high minimum denominations. This democratization sets in motion rules requiring public offerings to retail investors to meet disclosure and appropriateness criteria. For its wealthy customers in 2022, DBS Bank in Singapore started tokenizing corporate bonds into S$1,000 units while keeping strict control to guarantee compliance and openness (Garcia Ocampo et al., 2023).

Under rigorous control to maintain investor confidence, accessibility, and integrity, tokenized bond infrastructure is gradually spreading into the areas of trading, settlement, issuing, and custody.

3.4. Case Studies: Early Implementations and Lessons

Since 2018, several bond tokenization initiatives have been undertaken ranging from UBS's CHF 375M tokenized bond on SDX (Switzerland) to supranational entities like the World Bank's bond-i (Australia). Table 2 shows noteworthy issuances spanning 2018 - 2024. These initiatives reveal developments in real-world settlement applications (EIB, 2021; World Bank, 2023; HKMA, 2023; DLT integration; regulatory cooperation). Using DLT for primary issuing lifecycle management (HKMA, 2023), the 2023 tokenized green bond issued by Hong Kong, for instance, shortened the settlement time from T+5 to T+1.

Table 2: Major tokenized bond pilot issuances (2018 - 2024) (chronologically ordered)

Year	Issuer / Instrument	Amount	Jurisdiction	Platform
2018	World Bank - "bond-i" (1st blockchain bond)	110 mil. AUD (80 mil. USD)	Australia	Ethereum (private network)
2019	World Bank - bond-*i* (tap issue) (2nd tranche)	50 mil. AUD (36 mil. USD)	Australia	Ethereum (private network)
2021	European Investment Bank (2yr digital bond)	100 mil. EUR	France	Ethereum (public chain)
2022	UBS AG (senior unsecured digital bond)	375 mil. CHF (370 mil. USD)	Switzerland	SDX (SIX Digital Exchange)
2023	H.K. Government (tokenized green bond)	800 mil. HKD (101 mil. USD)	Hong Kong	Goldman/HKMA private DLT
2023	Banque de France & Luxembourg (Venus project bond) (semi-wholesale CBDC)	100 mil. EUR	Luxembourg	Private DLT (GS DAP)
2024	World Bank (digital CHF bond)	200 mil. CHF (220 mil. USD)	Switzerland	SDX w/ SNB wholesale CBDC
2024	Siemens AG (blockchain note) (under eWpG law)	300 mil. EUR	Germany	SWIAT DLT network

Sources: World Bank (2018, 2024), European Investment Bank (EIB, 2021), UBS (2022), Hong Kong Monetary Authority (HKMA, 2023), Siemens (2024), International Capital Market Association (ICMA, 2024).

The practical applications of tokenized bonds from 2018 to 2024 underline both advantages and drawbacks of this development. Apart from the listed World Bank and EIB projects, several more pilots have been carried out in other regions:

- Thailand's Blockchain Bond: Using a blockchain-based system, the Thai government teamed with IBM Hyperledger technology to create savings bonds available to the general public in 2020. Targeting individual investors, the bonds were sold fast via a mobile app from modest values, demonstrating public demand when entrance restrictions are taken off. Though it was carried out under government control in a permissioned setting, the initiative proved that it was feasible to widely distribute government debt via DLT.
- Oman's Private Corporate Bond: An Omani oil business issued a tokenized bond valued 10 mil. USD on a private ledger in 2020 using HSBC and other institutions. One of the first in the Middle East, this shows that even in usually conservative markets blockchain technology may enhance bond issuing procedures. if it remained mostly closed, the pilot demonstrated that international banks could cooperate to use DLT for corporate debt transactions even if the pilot was a private placement.
- SIX Digital Exchange (SDX) in Switzerland: Launched a fully regulated digital exchange platform and issued its own 150 mil. CHF bond in 2021 exclusively in tokenized form, although being a member of the SIX stock exchange group. A revision of Swiss legislation, the DLT Act acknowledged the ledger entries as official proof of ownership and let this bond to exist just on the SDX distributed ledger without a paper certificate. Investors maintained their positions in digital custody accounts; the SDX bond was traded on the SDX platform. Under supervision of the Swiss Financial Market Authority, this case is a great illustration of how to include tokenization into the framework of a conventional exchange. Even in a closed ecosystem, it established that a national stock exchange can directly issue and administer a bond on blockchain, therefore attaining settlement (same-day completion) and constant trading efficiencies.
- Hong Kong Green Bond: A important sovereign issuance on DLT, Hong Kong's tokenized green bond (2023) is as discussed already. Smart contracts controlled the bond's operations - interest payments, redemption - after it was issued. HKMA claims that investors responded positively and the platform enabled a more effective procedure with less middlemen. The success of this initiative has attracted interest in using tokenization in Hong Kong's bigger bond program, hence possibly tying in with the bond markets of mainland China for cross-border pilots.

- Other Notable Initiatives: Following its public Ethereum trial in 2021, the European Commission's European Investment Bank has continued forward, releasing a digital bond on a private permissioned platform (Goldman Sachs's GS DAP) in 2022. Although regulatory uncertainty has hampered US development, one notable example is Exodus, a blockchain business qualified to issue a Regulation A+ tokenized bond (essentially, a public issuance of debt instruments represented by tokens on the Algorand network) in 2021. This proved that, although not easy, it is possible under present US law to do a compliant public tokenized securities offering. International organizations including the Asian Development Bank (ADB) and various central banks are investigating or running small pilot programs to better understand the dangers and operational mechanics of tokenized bonds. For instance, the HKMA's green bond pilot made use of common data standards for tokenized bond issuances, which the International Capital Market Association (ICMA) has been developing - akin to a standardized taxonomy for bond information in DLT form. Furthermore, intervening are industry groupings. Apart from continuous efforts by ISO and other entities, these standards initiatives are regarded as crucial to preserve interoperability and prevent fragmentation in the case that several platforms issue tokenized bonds (BIS, 2024).

Case studies reveal possible risks as well as opportunities. Positively, tokenized bonds have definitely proven more efficiency. The EIB's blockchain bond settled in one day (T+1) instead of five (T+5), therefore reducing counterparty risk and intermediary fees unlike those of traditional syndications. Experience of Hong Kong also revealed more openness and faster company decisions (Chan, 2024). These gains increase liquidity and help to reduce issue costs. Tokenization has made imaginative ideas like green bonds - which let investors track project impact in real time using on-chain data or Internet of Things oracles plausible.

Still, risks exist. Faster settlement lowers error correction time; on-chain reversals are complex and need a strong smart contract architecture and contingency measures (FSB, 2023). Legal uncertainty still remains in several nations, most famously with regard to the finality of token transfers and bondholder rights after default, even while revisions are under process (Garrido, 2023). Market fragmentation is another issue; liquidity may suffer if tokenized bonds are issued on several incompatible systems. This emphasizes the need of linking DLT networks and legacy infrastructure under standard criteria (BIS, 2024; Lavayssière, 2025).

Ultimately, investor protection requires change. Investors require disclosures and protections like those seen in traditional markets as retail access rises to help to avoid confusion between regulated bond tokens and speculative crypto-assets (OECD, 2020).

3.5. Outlook and Financial Stability Considerations

It is anticipated that tokenized bonds will move from pilot programs to become a commonplace feature of fixed income markets. As regulatory clarity improves, corporations are anticipated to follow governments that are investigating blockchain for the issuance of public debt. Through 2025 - 2026, a number of European sovereigns intend to make additional tokenized offerings under the EU Pilot Regime, which could establish digital bonds as a common debt management tool.

Even though the tokenized markets are still small today, the Financial Stability Board (FSB) cautions that if they grow too quickly, they may face risks like technological malfunctions, cyberattacks, or legal ambiguities (FSB, 2023). By simplifying settlement and lowering counterparty exposure, tokenization may also improve resilience. Regulators emphasize the value of cross-border cooperation, stating that seamless legal recognition, regulatory equivalency, and unified standards are necessary for international interoperability. Discussions to address these needs are being led by organizations such as the BIS (BIS, 2024).

Studies are also looking at wider ramifications, such as possible improvements in financial inclusion by lowering investment thresholds and potential monetary policy repercussions if retail access increases (Garrido, 2023; IMF, 2023). In general, people are cautiously optimistic. Instead of being seen as destabilizing, tokenized bonds are seen as a technological advancement in market infrastructure. Maintaining trust is essential to their

success; they must make sure that technical dependability, legal certainty, and oversight are on par with or better than those of current systems (Lavayssière, 2025).

Notable progress has been made between 2022 and 2025. With strong legal foundations, ongoing testing, and promising evidence, tokenized fixed income products are becoming more and more likely to revolutionize international capital markets. Their capacity to provide efficiency and inclusion at scale will be put to the test in the following phase, or it will highlight areas that still require improvement.

4. Economic and Financial Implications

Real-world asset (RWA) tokenization has the potential to change macroeconomic dynamics by increasing market participation, improving liquidity, and unlocking capital. Tokenization improves capital allocation, speeds up settlement, and mobilizes previously illiquid savings by transforming financial and physical assets into fractional digital tokens (BIS, 2024; Aldasoro et al., 2023; Pu & Zulkafli, 2024). According to estimates, full-scale RWA tokenization could result in annual global efficiency gains of up to 2.4 trillion USD, particularly in FX markets. By 2030, conservative paths still suggest savings of tens of billions of dollars (Baltais & Sondore, 2024; McKinsey & Company, 2023).

To reap these advantages, regions are taking action. Since the SEC primarily views tokens as securities, tokenization has had little effect in the United States (Crenshaw, 2025). However, initiatives like DTCC's Ion demonstrate growing interest in blockchain post-trade systems. Europe has taken more decisive action in the meantime. In 2024, the EIB issued blockchain-native bonds, which included a 100 mil. EUR transaction settled through wholesale CBDC (Ledger Insights, 2024). Tokenized trading is made possible by the EU's DLT Pilot Regime, which strikes a balance between investor protection and innovation (ESMA, 2023).

Tokenization initiatives in Asia are spearheaded by Singapore's MAS. In 2025, it authorized the first tokenized retail money-market fund with a minimum investment of 20 USD, established industry standards, and started the Global Layer One initiative for cross-border interoperability (Maldonado, 2025). The goal of these actions is to increase the liquidity of the primary and secondary markets.

There is also activity in the Middle East. In order to draw in international investors, Dubai's regulators developed a specialized framework (VARA) and sandbox for real estate tokenization, transforming property titles into fractional tokens. The potential of tokenization to give traditionally illiquid assets like real estate "stock-like" liquidity is reflected in this initiative (Basri, 2025).

By fractionalizing assets and facilitating round-the-clock trading, tokenization can greatly increase market liquidity. On-chain platforms increase transparency, lower costs, and expedite settlement, while illiquid assets such as private debt and real estate become tradable (BIS, 2024). Using on-chain DvP, Hong Kong's tokenized green bond settled in T+1 versus T+5 (ICMA, 2024). Continuous liquidity is supported by automated smart contracts, and DLT-enabled collateral mobility has the potential to unlock more than 100 bil. USD yearly (WEF, 2023). Tokenization is viewed by Singapore's MAS as a means of enhancing liquidity across assets and currencies and tying markets together (Allen & Gledhill, 2024).

However, there are risks associated with liquidity gains. Token networks have the potential to intensify shocks, the IMF warns, particularly if platforms grow overly leveraged or interconnected (IMF, 2025). Additionally, single points of failure could be introduced by market concentration. Regulators are required to maintain appropriate governance, which is similar to traditional market safeguards. By removing obstacles to investment and decreasing dependency on middlemen, tokenization also improves financial inclusion. It makes previously inaccessible assets available to small investors, particularly in emerging markets. This change is best illustrated by Franklin Templeton's 20 USD retail fund in Singapore (Maldonado, 2025). New avenues for investment are made possible by fractional ownership of assets like infrastructure or gold, particularly through mobile wallets. BIS leadership highlights how token systems could empower marginalized populations by drawing a comparison between this leap and India's digital ID revolution (Carstens, 2025). Digital access and robust regulatory frameworks (AML, KYC, investor protection) are essential for success.

Slow payments, complicated foreign exchange, and disjointed systems are all issues that cross-border tokenization eliminates. Conditional settlement and currency conversion can be automated with smart contracts (OECD, 2021; BIS, 2024). The goal of Singapore's GL1 initiative is to harmonize technical and legal requirements for smooth international trade. For real-time global settlement, BIS-led pilots like Project Agorá and Pine investigate government bonds, tokenized deposits, and CBDC. Dubai uses blockchain to access international real estate, and the EIB has tested multi-currency digital bonds (Basri, 2025).

Central banking is also called into question by tokenization. By functioning outside of conventional reserve and settlement frameworks, a token-based system has the potential to change the way money is transmitted. Three impact channels are highlighted by BIS research: (1) operational - token networks may function around-the-clock under specific regulations; (2) money supply - the demand for central bank reserves may be impacted by the widespread use of tokenized currency (Shin, 2024); and (3) market structure - integrated platforms may change the way liquidity and funding are handled (Agur et al., 2025). Token settlement is possible, according to ECB-EIB trials with wholesale CBDC. Future systems that combine securities, tokenized currency, and CBDC are envisioned by BIS leadership (Carstens, 2025). Central banks are getting ready for policy and regulatory adaptation, even though the long-term macro effects are unclear (BIS, 2024).

5. Challenges, Conclusions, and Policy Recommendations

Increased liquidity, transparency, and efficiency are potential benefits of real-world asset (RWA) tokenization; however, adoption has been sluggish because of a number of obstacles. These include market fragmentation, institutional resistance, technological immaturity, cybersecurity vulnerabilities, scalability and interoperability constraints, and regulatory and legal uncertainty. Approaches vary widely around the world (as we have compiled in Table 1).

Regulatory and Legal Uncertainty

Without obvious labels, tokenized RWAs straddle the boundaries of property law, commodities, and securities. Offerings must adhere to disclosure and licensing requirements since tokens in many nations default to current securities laws (Openware, 2024). For instance, new RWA structures are uncertain because US regulators apply the Howey Test to tokens; this ambiguity has not yet been resolved by pending proposals like the "Token Safe Harbor." Similarly, the EU's DLT Pilot Regime is still time-limited and has a limited scope, and the MiFID II and MiCA frameworks do not specifically address security tokens (Better Finance, 2023). A new EU investor group has called for more precise legal distinctions and cautioned that MiCA does not define "hybrid" tokens. However, despite the fact that many RWA use cases are still awaiting specific legislation, Singapore's Monetary Authority (MAS) has actively issued guidance (for example, through "Project Guardian") and worked with others on market regulations (MAS, 2022). The UAE is actively developing a comprehensive token regime: the onshore Securities and Commodities Authority (SCA) just recently began consultations on new security-token regulations, the DIFC issued a Digital Assets Law in 2024, and Dubai's VARA oversees crypto services (Man & White, 2025). In summary, traditional financial institutions like banks and insurers that need regulatory certainty and standardized frameworks before investing capital are still discouraged by the persistence of legal ambiguity (Openware, 2024; Man & White, 2025) (Basar, 2023).

Technological and Infrastructure Challenges

RWA blockchain platforms are still in their infancy. Public ledgers perform far worse than traditional financial systems due to their low throughput (Ethereum, for example, processes only 10 to 15 transactions per second) and high transaction costs during congestion. Faster processing is possible with private or permissioned DLT solutions, but decentralization is frequently compromised, and there are no standardized protocols. Although smart contract technology is developing, tokenized assets are still at risk of loss due to coding errors and inadequate auditing. Recent industry analyses have observed that tokenization initiatives are often restricted to "walled-garden"

ecosystems and are still primarily in early-stage pilot phases (Deloitte, 2024). Unified digital identity systems, interoperable cross-chain settlement layers, and wholesale central bank digital currencies (CBDCs) are examples of critical supporting infrastructure that is still lacking. While recognizing that no platform has yet attained scale or ecosystem-wide adoption, the Monetary Authority of Singapore (MAS) has started projects like the "Global Layer One" project and a new SGD token testnet with the goal of building shared infrastructure (Leong, 2024). Market players are still apprehensive because they fear that tokenized assets cannot yet be issued, transferred, or settled at scale in a secure and effective manner without strong, scalable platforms and institutional-grade custodial services (Shin, 2024; Openware, 2024; Deloitte, 2024).

Market Fragmentation and Liquidity Issues

At the moment, tokenized assets are traded on non-interoperable exchanges and in siloed networks. For RWA tokens, there is no one marketplace or industry standard; instead, various platforms frequently use unique formats, protocols, and settlement processes. "Most tokens cannot be traded or redeemed outside the platform used or created by the issuing entity," according to industry research (Deloitte, 2024). Liquidity is hampered by this ecosystem fragmentation. In theory, tokenization makes secondary markets more accessible and fractionalized, but in reality, there aren't many of these markets. As we noted in Table 2, early pilot programs show isolated transactions with a small volume of continuous trading. In the event that tokenized markets grow without sufficient market-making procedures and regulatory supervision, the Financial Stability Board (FSB, 2024) has also issued a warning about possible liquidity shortages and maturity mismatches. Only a few investors may be drawn to token sales in specialized RWA industries like fine art or real estate, which would increase price volatility. Therefore, platform fragmentation and inadequate liquidity remain significant obstacles to the broad adoption of RWA tokens (Openware, 2024).

Institutional Trust and Adoption Barriers

Many conventional financial institutions are still dubious. Asset managers and legacy banks are hesitant to invest in untested infrastructure (Deloitte, 2024). According to surveys, investors anticipate higher yields or insurance to offset perceived risks, even though interest in tokenized assets is growing (Basar, 2023). According to respondents, trust is diminished by regulatory ambiguity, custody uncertainties, and inexperienced governance (Basar, 2023; Deloitte, 2024). Furthermore, institutional participants may oppose new technologies unless they demonstrably outperform existing systems because they value established intermediaries. Uptake is further hampered by the absence of well-known custodial and settlement services for tokens. Many tokenization pilots have only succeeded in achieving proof-of-concept by "avoiding many of the challenges they might face outside of their own carefully controlled platforms," according to one industry report (Deloitte, 2024). Clear guidance from standards organizations and regulators will be necessary to remove these obstacles (Basar, 2023; Deloitte, 2024).

Scalability, Interoperability, and Standardization

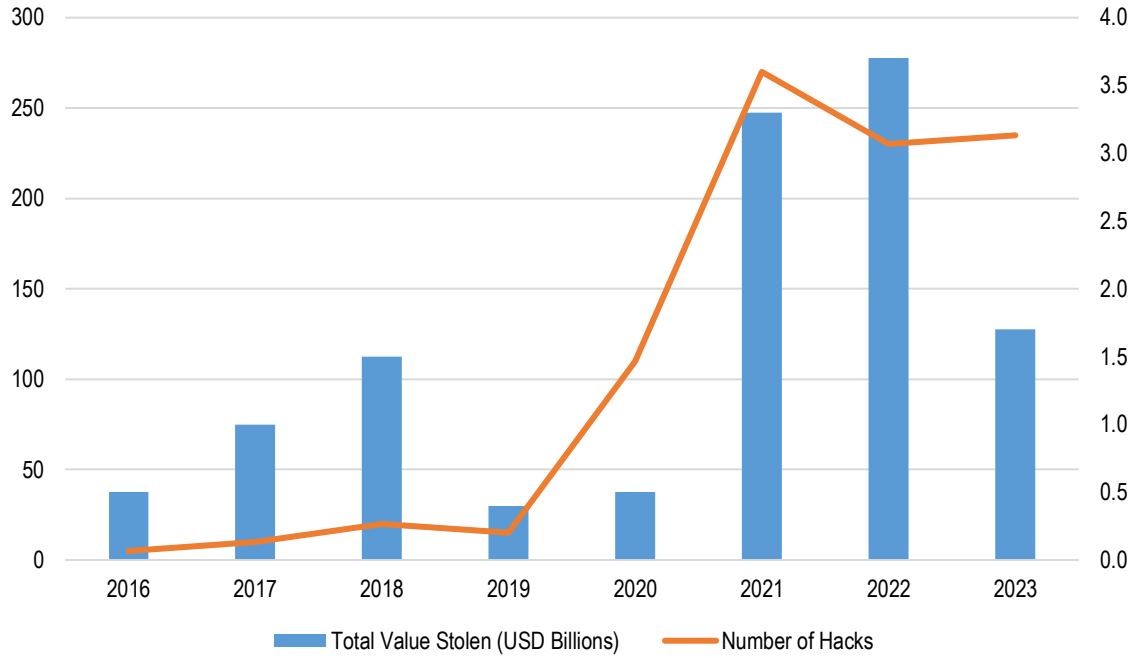
The scale of blockchain networks today is not comparable to that of traditional financial infrastructures. Current blockchain capabilities cannot handle high-throughput demands, like those found in international bond markets. Although they are being developed, suggested scaling solutions like layer-2 networks and sharding have not yet been validated at the institutional level. Additionally, there is limited interoperability: tokens issued on one chain hardly ever move easily to another. According to industry experts, "institutions should go outside their walls" and adopt common protocols in order to "unlock and maximize the potential of these use cases" (Deloitte, 2024). Although they are still in the early stages of development, standards for token formats, smart contract templates, and messaging - such as ISO/TC 307 blockchain standards or ISO 20022 - will be crucial (MAS, 2024; Deloitte, 2024). Fragmentation endures in the absence of interoperability because every new RWA marketplace necessitates bridging across ledgers, which raises complexity and costs. All things considered, current token

networks are unable to support the volume or integration required for major asset classes due to scalability and fragmentation issues (Deloitte, 2024; MAS, 2024).

Cybersecurity and Operational Risks

All of the cyberthreats associated with cryptocurrency are present for tokenized assets. As multiple cryptocurrency hacks have demonstrated, smart contracts may have errors or weaknesses (Figure 4). According to Chainalysis, hackers stole almost 5.4 bil. USD from cryptocurrency platforms in 2022 and 2023 combined (Chainalysis, 2024).

Figure 4. Yearly total value stolen in crypto hacks and number of hacks (2016 - 2023)



Note: Cybersecurity threats remain significant; Chainalysis reports that stolen crypto assets peaked at 3.7 bil. USD in 2022 before falling to 1.7 bil. USD in 2023, reflecting persistent vulnerabilities in blockchain systems.

Source: Chainalysis (2024) (chainalysis.com)

The frequency of incidents increased in 2023 despite a decrease in the total hacked value, highlighting enduring threats like code exploits, insider compromises, and bridge attacks. Oracles that link token contracts to off-chain data, for instance, can be manipulated, and private key loss is still a significant risk with tokenized RWAs. Because "technological infrastructures... are in their baby stage," as Openware (2024) points out, there is still a high risk of coding errors and hacking. Additionally, custody services are not well-developed, and entire assets could be compromised by wallet breaches. To increase institutional confidence, these risks necessitate thorough audits, cyber insurance, and separating the infrastructure of tokenized assets from unstable crypto systems.

Case Studies by Jurisdiction

- United States: US regulators typically apply current securities laws to tokens, requiring issuers to register with the SEC or meet exemption requirements. The majority of RWA tokens are treated as securities by the SEC, which creates compliance burdens (Uyeda, 2025). Although state-level innovations (like those in Wyoming) provide some respite, there is no federal sandbox. The necessity of "transparency and predictability" in crypto policy was highlighted in a 2025 SEC roundtable (Uyeda, 2025). However, institutional adoption has been discouraged by regulatory enforcement actions. Although a new regulatory framework tailored to tokens has been proposed, it has not yet been implemented. Mainstream institutional entry may be delayed by the fragmented regulatory environment in the United States.

- European Union: The EU has adopted a more assertive posture. Utility and e-money tokens are governed by MiCA (2023), whereas security tokens are still subject to MiFID II. Limited testing of blockchain-based exchanges and settlement infrastructures is made possible by the DLT Pilot Regime (2023). However, there are still issues: the regime is only temporary, and national laws - like France's PACTE Law and Germany's eWpG - are fragmented (ESMA, 2023; Better Finance, 2023). Harmonization is still in progress, but ESMA is working on additional guidelines.
- Singapore: In terms of tokenization, MAS has become a world leader. More than 40 institutions have tested tokenized funds, bonds, and foreign exchange trading through Project Guardian (MAS, 2022; Leong, 2024). Token taxonomies and regulatory sandboxes have been introduced by MAS. Officials acknowledge that there are still infrastructure gaps and that scale has not yet been reached. Pilots and the creation of standards have been made possible by Singapore's approach, which has been supportive rather than restrictive (Leong, 2024).
- United Arab Emirates: The country is purposefully positioning itself as a center for tokenization. The DIFC's 2024 Digital Assets Law now formally recognizes digital assets under property law, and Dubai's VARA started licensing cryptocurrency companies in 2022 (Man & White, 2025). The creation of a national Security Token Regime is underway. Although there may be initial coordination issues due to the UAE's dual legal system (onshore and free zone), the general policy direction is encouraging. Although the first pilots have been small, more are anticipated as frameworks are finalized (Man & White, 2025).

Policy and Regulatory Solutions

Coordinated policy action will be necessary to overcome these obstacles. First and foremost, governments must establish token categories and implement appropriate regulations in order to ensure regulatory clarity (Basar, 2023). Public safe harbours or pilot sandboxes with explicit regulations (like the EU DLT Pilot Regime) or amending securities laws to specifically allow DLT-based issuance are a few examples of this. Cross-border legal conflicts would be lessened by international harmonization (Financial Stability Board, 2024). Technical barriers can be removed by investing in standards and infrastructure. For example, industry consortia and central banks can support digital currencies or common ledgers that work with token networks, such as FedNow. Interoperability would be facilitated by supporting industry API protocols or ISO/TC 307 blockchain standards (Deloitte, 2024). Third, regulators can promote insurance and custodian frameworks to foster trust and give institutional investors a sense of security. To test actual issuance conditions, public-private partnership pilot projects (like the EU's sandbox exchanges or Singapore's Project Guardian) ought to be extended (Leong, 2024; MAS, 2022). Fourth, operational risk can be reduced by addressing cybersecurity through stricter code-audit requirements, incident reporting - possibly utilizing frameworks like the FSB's FIRES - and cross-sector information sharing (FSB, 2024). Last but not least, widespread education and communication among regulators, incumbents, and innovators (for instance, through task forces and industry associations) will aid in incentive alignment. Tokenization is a slow, multifaceted process that, according to Basel-based economists, will probably need industry cooperation on standards and regulatory involvement to realize its full potential (Shin, 2024; Deloitte, 2024; Cointelegraph, 2023).

Conclusions

The limited real-world adoption of tokenized RWAs is progressing from pilot stages. The first public bond settled on a blockchain, the World Bank's 2018 bond-i (100 mil. AUD), is one example of a blockchain-based security issued by major institutions (World Bank, 2018).

Enabling laws have been passed in a number of places. Blockchain was acknowledged by France in 2019 as being on par with conventional securities ledgers (Carvalho, 2019). Switzerland's DLT Act (2021) permitted "ledger-based securities" and DLT trading licenses, while Germany's 2021 eWpG established a new category of "electronic securities" (ESMA, 2023a) (Cointelegraph, 2024). The DLT Pilot Regime establishes a sandbox for trading tokenized MiFID instruments on authorized DLT platforms, while MiCA (effective 2023) regulates asset-backed crypto tokens at the EU level (Better Finance, 2023).

Regulators are actively participating on a global scale. Singapore's MAS is testing CBDC/tokenization sandboxes and has formalized Project Guardian for tokenized bonds and funds (MAS, 2022). Project Ensemble (2024) was started by Hong Kong's HKMA to test tokenized settlement and wholesale CBDC (HKMA, 2024). Crypto-asset services are licensed under the UAE's VARA framework (Bird & Bird, 2025). Pilots and regulatory working groups in the US and the UK are investigating safe and sound tokenization strategies (State Street, 2024).

These changes show fragmentation while also reflecting growing regulatory acceptance. The need for more international alignment is highlighted by frameworks that range from strict securities laws to encouraging sandboxes.

The tokenized asset infrastructure is developing quickly. Fintechs and exchanges have developed specialized platforms such as Singapore's TokenX, JPMorgan Onyx, Goldman Sachs' GS DAP, and Switzerland's SDX (WEF, 2023; BIS, 2024). DLT networks like Ethereum and Hyperledger, as well as consortiums like Fnality, ALPS, and Project Ion, are being modified for institutional use (McKinsey & Company, 2023).

Tokenized systems are being piloted by central banks: the UK is investigating a DLT-based Digital Securities Sandbox for post-trade efficiency, while Brazil's DREX and Colombia's wholesale CBDC use DLT (BIS, 2024; State Street, 2024). Benefits like quicker settlement, less reconciliation, embedded compliance, and new asset classes like fractional ETFs are highlighted in industry studies (Deloitte, 2024).

There is early momentum. JPMorgan's Onyx repo platform processed over 300 bil. USD in intraday trades, while tokenized money market funds (BlackRock, Franklin Templeton) exceeded 1 bil. USD in Q1 2024 (Franklin Templeton, 2023; Deloitte, 2024). More than 10 bil. USD in tokenized bonds have been issued by governments and corporations (World Bank, EIB, Siemens, Thai, and Philippine agencies) (Ledger Insights, 2024).

However, fully integrated ecosystems are still in their infancy, with broad secondary market liquidity and digital cash rails. The majority of pilots lack the network effects and common standards necessary for scale because they are isolated (Cointelegraph, 2023; Nethermind & PwC, 2025).

If obstacles are removed, market research predicts rapid growth. By the end of the decade, tokenizable global assets could amount to tens of trillions, according to established studies. For instance, Roland Berger and Boston Consulting Group estimate a range of 10 to 16 trillion USD by 2030 - 2031 (Banerjee et al., 2024), while McKinsey projects roughly 26 trillion USD by 2030 (McKinsey & Company, 2023). A 50% compound annual growth rate is implied by a recent industry analysis that projects 16.1 trillion USD by 2030 (Nethermind & PwC, 2025). Even with this promise, the size of tokenized real-world assets held worldwide remained small; by the end of 2024, Investax reported holding approximately 15.2 bil. USD (Tokenized Asset Coalition, 2024). Institutional interest is increasing, according to surveys. For example, EY-Parthenon (2023) reported that 61% of high-net-worth individuals and 37% of institutional investors planned to invest in tokenized assets between 2023 and 2024. ETFs and tokenized funds may also grow significantly; according to one analysis, by 2030, tokenized funds may account for 1% of all assets under management, or about 600 bil. USD (Invesco, 2023).

Faster clearing and settlement, increased investor reach, and automated asset servicing are just a few of the observable efficiency benefits that tokenization provides. These benefits can reduce operating expenses and increase market liquidity (McKinsey & Company, 2023; Deloitte, 2024). Smaller investors may be able to access historically illiquid markets and improve capital allocation through increased liquidity and asset fractionalization. Nonetheless, policymakers correctly identify a number of hazards.

The International Monetary Fund (IMF) and Bank for International Settlements (BIS) have conducted analyses that indicate tokenized systems introduce new financial risks, including coding errors, cybersecurity threats, and governance vulnerabilities, in addition to the conventional ones, like credit, liquidity, and operational risk (Bank for International Settlements, 2024; IMF, 2025). The IMF cautions that if DLT-based trading protocols are overused, they may increase volatility if improperly regulated, and that incomplete interoperability could lead to systemic frictions (IMF, 2025). Similar warnings are issued by the Financial Stability Board (FSB, 2024), which states that unbridled growth of tokenized finance without corresponding regulatory development could jeopardize overall financial stability. These dynamics are being closely monitored by central banks: experimental initiatives like the US Project Pine at the Federal Reserve is looking into how tokenized collateral and programmable tokens could change the way money is implemented (US Federal Reserve Bank of St. Louis, 2024). Preserving the "singleness of money" - making sure that commercial bank and central bank money continue to operate interchangeably, especially as tokenized deposits and CBDCs develop - is a critical macroeconomic concern (FSB, 2024; State Street, 2024).

Adoption obstacles are still very strong. According to surveys and market analyses, the main barriers to scale are fragmented legal standards and regulatory uncertainty (Nethermind & PwC, 2025; Cointelegraph, 2023). Institutional actors also point to unclear cross-border recognition regulations, limited liquidity pools, and a lack of standard protocols as barriers to more robust deployment (Basar, 2023). Additional barriers include both high integration costs with legacy financial systems and technical limitations, such as weak privacy mechanisms and insufficient transaction throughput on blockchains (Baker McKenzie & Deutsche Bank, 2025). Building investor trust is still essential, and tokenized products need to adhere to current AML/KYC regulations and investor protection frameworks. Due to protracted proof-of-concept phases that don't scale or generate financial returns, many organizations claim to be suffering from "pilot fatigue" (Deloitte, 2024). Since most tokenized securities today don't have active secondary markets, issuers are forced to hold tokens until they mature, essentially reproducing traditional buy-and-hold structures in a digital form (Deloitte, 2024). This emphasizes how important it is to have clear regulations and a strong secondary-market infrastructure.

Policy Recommendations

Drawing from the analysis and conclusions presented, the following policy recommendations aim to support the safe and sustainable scaling of tokenization. These proposals are tailored to the needs of key stakeholder groups - regulators, financial institutions, market participants, and infrastructure developers - and reflect international best practices and evolving regulatory standards.

For Regulators

Policymakers must provide clarity on the role of tokenized real-world assets (RWAs) within legal and financial systems. This includes developing unambiguous, technology-neutral legal frameworks that define tokenized deposits, securities, and stable coins according to applicable regulations. For instance, countries like France, Germany, and Switzerland have amended their laws to recognize securities based on distributed ledger technology (DLT) (Carvalho, 2019; Cointelegraph, 2024). Additionally, regulatory models such as the UAE's VARA and DIFC frameworks serve as references (Man & White, 2025). To ensure consistency and legal certainty, classification standards should be precise and uniform (European Banking Authority, 2024).

Promoting innovation through regulatory sandboxes is essential. Initiatives such as the EU's DLT Pilot Regime, Hong Kong's sandbox environment, and Dubai's real estate tokenization pilots exemplify safe environments for experimentation (ESMA, 2023; HKMA, 2023). However, to mitigate risks of fragmentation and regulatory arbitrage, international coordination is necessary. Organizations such as the Financial Stability Board (FSB) and the Bank for International Settlements (BIS) should collaborate on setting cross-border standards for messaging protocols, data formats, and custody practices (FSB, 2024; Deloitte, 2024).

Tokenization must be supported by robust security, governance, and investor protection mechanisms, including compliance with Anti-Money Laundering and Countering the Financing of Terrorism (AML/CFT) regulations. Singapore's regulatory approach to stablecoins offers a strong model in this regard (MAS, 2023). Further regulatory clarity is also needed in areas such as capital treatment and the custody of tokenized assets. For example, systemic implications have been highlighted in the United States following the SEC's proposal on bank custody (State Street, 2024). Regulations should enforce transparency in token use and monitor concentration risks to maintain financial stability (FSB, 2024).

Global coordination is vital for the success and scalability of tokenization. International bodies such as the International Organization for Standardization (ISO), the Committee on Payments and Market Infrastructures (CPMI), and BIS are actively developing tokenization frameworks. Regulators must harmonize token data models, custody standards, and adopt ISO 20022 messaging protocols to facilitate interoperability (FSB, 2024; BIS, 2024). Legal and technical alignment is particularly important to enable seamless cross-border flows, including interoperable Know Your Customer (KYC) and Central Bank Digital Currency (CBDC) systems (Deloitte, 2024; Allen & Gledhill, 2024).

For Financial Institutions and Market Participants

Financial institutions are encouraged to invest in the internal capabilities necessary to participate effectively in tokenized markets. This includes developing secure transfer mechanisms, digital custody infrastructure, and compliant recordkeeping systems. According to Deloitte (2024), early adopters with robust operational experience will gain a competitive advantage. Institutions should also evaluate their accounting, treasury, and risk management systems for DLT integration and provide specialized training in blockchain technologies, smart contracts, and token lifecycle management (Banerjee et al., 2024).

Participation in industry consortia and standard-setting bodies (e.g., ISO/TC 307, ISO/TC 68) is essential to promote interoperability and adherence to global standards. Collaborative initiatives such as the Bank of England's Project Ion and Singapore's Project Guardian underscore the importance of coordinated regulatory and technical action (MAS, 2022; BIS, 2024). Harmonization in asset definitions, custody rules, and settlement practices will be critical to facilitating cross-platform liquidity (FSB, 2024).

To operationalize tokenization, market participants should initiate targeted pilot projects focusing on practical use cases such as automated coupon disbursements, fractional ownership of illiquid assets, and real-time settlement. The World Bank's bond-i and the European Investment Bank's blockchain bonds illustrate the feasibility of DLT-based financial instruments (World Bank, 2018; EIB, 2021). Asset managers are also experimenting with tokenized ETFs. For scalability, these pilots must integrate stringent controls over wallet security, smart contract validation, and liquidity risk management (FSB, 2023).

In addition, financial institutions should proactively engage with regulatory bodies to contribute to the development of clear and predictable legal frameworks. Participation in consultative processes such as the EU's DLT Pilot Regime and MiCA consultations plays a pivotal role in shaping effective regulatory outcomes (ESMA, 2023; Better Finance, 2023). Critical policy areas include capital eligibility for tokenized assets, accounting treatment, and taxation. As emphasized by Deloitte (2024), the design and implementation of tokenization policy require active collaboration between the public and private sectors.

For Infrastructure and Technology Developers

DLT developers and infrastructure providers must prioritize interoperability and compliance by designing systems that support integration through open protocols, standardized APIs, and ISO 20022 messaging formats (FSB, 2024; BIS, 2023). Adoption of unified data models and whitelisted frameworks will facilitate cross-jurisdictional regulatory compliance and consistency in KYC processes (Deloitte, 2024).

Security and operational resilience must be core design principles for tokenization platforms. The inherent risks of DLT - including code vulnerabilities and oracle manipulation - necessitate advanced safeguards such as multi-signature custody solutions, formally verified smart contracts, and robust disaster recovery systems (Chainalysis, 2024). Regulatory collaboration on audit procedures and system certifications can further strengthen trust. Privacy-preserving technologies such as zero-knowledge proofs are particularly valuable for deployment in regulated sectors (IMF, 2023; BIS, 2024).

Scalability and user accessibility also require significant attention. DLT platforms should offer high throughput and low latency, utilizing innovations such as sharing, permissioned blockchains, and Layer-2 scaling solutions (Nethermind & PwC, 2025). The development of modular compliance workflows, token issuance toolkits, and intuitive user interfaces will encourage adoption among both institutional investors and smaller market participants (MAS, 2024; Banerjee et al., 2024).

Finally, the economic integration of tokenized markets with existing financial infrastructure is essential. Platforms like JPMorgan's Onyx, as well as stablecoins and CBDCs, serve as bridges to traditional monetary systems (Ledger Insights, 2024; MAS, 2023). Ensuring interoperability with legacy networks, including FedNow and SWIFT, will help avoid fragmentation and anchor tokenization within the broader financial ecosystem (FSB, 2024; IMF, 2023).

Credit Authorship Contribution Statement

The author contributed to all aspects of this research. Specifically, all conceptualization, study design, methodology selection, data collection, and formal analysis were carried out by the author.

Conflict of Interest Statement

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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