Fraud in tokenization: A real world problem

NIKITA MIKHAILOVIC FROLOV, University of Twente, The Netherlands

Abstract - Commodity market tokenization, which entails issuing digital tokens backed by physical commodities, increases trading efficiency but also raises the possibility of fraud. An extensive review of academic literature and industrial sources has been done. This study investigates how well tokenized commodity markets handle fraud-related risks. It specifically looks at what kinds of fraud are most common in traditional commodity markets, what legal and technical safeguards tokenized platforms put in place, and how successful these measures are at preventing fraud. The results demonstrate that, similar to traditional markets, insider trading, market manipulation, and collateral misrepresentation continue to be fraud concerns in tokenized environments. Oracles and smart contracts are examples of blockchain technologies that improve transparency and automate processes, but they are insufficient to completely remove all risks, especially those related to the connection between digital tokens and tangible assets. Responses from regulators are emerging, such as the European Union's Markets in Crypto-Assets regulation and various national securities laws, are emerging but remain fragmented, offering some oversight yet lacking global harmonization. The study comes to the conclusion that tokenization does not automatically fix fraud vulnerabilities, even though it offers new security features and increased transparency. To successfully prevent fraud and maintain market integrity in tokenized commodity markets, a combination of strong technical protections and more unified regulatory frameworks is needed.

Additional Key Words and Phrases: Tokenized Commodities, Blockchain Technology, Fraud Prevention, Digital Assets, Real-World Asset (RWA) Tokenization, Smart Contracts, Asset Tokenization, Commodity Markets, Digital Asset Trading, Blockchain Risks, Enterprise Blockchain, Decentralized Finance

1 INTRODUCTION

Imagine owning a fraction of the Mona Lisa or a square meter of the Burj Khalifa with just a few clicks, without banks or brokers. Blockchain is a Distributed Ledger Technology (DLT) that securely records transactions by hashing a linked sequence of blocks containing data which thus can have added elements of transparency, verifiability, and resistance to tampering without centralized control [20]. Features can vary depending on the type of blockchain. Anyone can join a public blockchain, view data, and validate transactions, private blockchains only give access to certain participants, providing more privacy and making them more appropriate for business settings. In 2008, Satoshi Nakamoto presented the first blockchain in the Bitcoin whitepaper, which suggested a public peer-to-peer electronic currency system on the blockchain [36]. This cash system currently has a market cap of $2.2 trillion, as of 10th of June 2025. Blockchain applications have undergone evolution over the years. One notable advancement is the tokenization of real-world assets (RWAs). This refers to the process of converting ownership rights to RWAs into digital tokens embedded onto a blockchain, akin to digital twins [46]. These tokens can represent commodities [20], real estate [23], or artwork [4]. Blockchain networks allow for the buying, selling, and trading of these digital tokens [44]. Tokenization can introduce a new model for asset ownership and investment.

TScIT 43, July 4, 2025, Enschede, The Netherlands

However, a number of operational and security risks are also introduced by this integration of digital and physical systems. The value of a commodity token is dependent on the proper certification, audit, and secure storage of the underlying asset. The collateral backing the token could be at risk if these mechanisms do not function properly or if information regarding them is vague or insufficient. This risk is heightened by the decentralized and frequently unclear characteristics of numerous blockchain platforms, which can raise questions regarding asset ownership or fraud [20]. Fraud refers to deliberate deception intended to secure unfair or unlawful gain. One broad definition is "the obtaining of goods and/or money by deception", a definition that captures the core element of intentional dishonesty for unlawful gain. [33]. Traditional commodity markets have long grappled with fraud risks, particularly in areas such as asset custody, falsified audits, and misrepresented collateral. This provides a useful reference point for assessing how fraud manifests and is mitigated in tokenized environments [14, 50].

Despite the growing adoption of tokenized commodities, there remains a gap in scholarship in understanding how platforms manage the risks they face, especially as these platforms potentially involve non-professional investors and transactions, which is particularly significant in the context of regulation. While the literature highlights several efficiency gains such as lower transaction costs, faster settlement [55], greater liquidity [48], and transparency through immutable records[20], it also acknowledges risks related to fraud, including smart contract exploits, market manipulation, and misrepresentation. However, it does not specifically examine how current tokenized commodity platforms are addressing these risks in practice.

2 PROBLEM STATEMENT & RESEARCH QUESTIONS

Although the literature extensively discusses the potential benefits of tokenization, there is limited investigation into the specific types of fraud that occur within tokenized commodity markets or how current platforms are responding to these risks. As such, there is a pressing need to begin exploring how fraud occurs in tokenized commodity systems and how it might be addressed in practice.

Main research question (RQ): To what extent do existing tokenized commodity platforms address fraud-related risks? *Hypothesis (H0):* Existing tokenized commodity platforms address certain types of fraud through blockchain-enabled transparency and automation, but do not fully eliminate fraud risks due to challenges such as verification of physical assets and regulatory fragmentation.

Sub-research question 1 (SRQ1): What types of fraud are most prevalent in commodity markets? *Hypothesis 1 (H1):* The most prevalent types of fraud in commodity markets include market manipulation, insider trading, and misrepresentation of collateral.

Sub-research question 2 (SRQ2): What technical and legal safeguards currently exist for tokenized commodity markets, and how effective are they? *Hypothesis 2 (H2):* Technical safeguards such as blockchain immutability, smart contracts, and oracles can improve traceability and automate compliance. However, these innovations can also bring new surfaces for fraud. *Hypothesis 3 (H3):* Legal and regulatory frameworks across jurisdictions are inconsistent, and their fragmented implementation limits the overall effectiveness of safeguards against fraud in tokenized commodity platforms.

3 BACKGROUND

3.1 Tokenization and Blockchain Technology

The foundation of asset tokenization is DLT. Blockchain is essentially a decentralized network that maintains a ledger of transactions in the form of a chain of blocks [26, 53]. Transactions and blocks are linked using cryptographic methods, allowing the system to automatically verify transaction validity. With the decentralization aspect of blockchain, tokens require terms and agreements without an intermediary, which is done with smart contracts. Smart contracts are self-executing contracts with the terms of the agreement written into lines of code. They automatically enforce and execute the terms of a contract, which is publicly verifiable on the blockchain [52]. Smart contracts are not a new concept. Nick Szabo, an American computer scientist described smart contracts as "computerized transaction protocols that execute the terms of a contract" [55]. With the emergence of blockchain technology, the efficiency of smart contracts has been significantly enhanced. [23]. These contracts can incorporate a database linking public addresses with token amounts, internal logic like transfers, static data, and an interface. Once live on a blockchain, the smart contract cannot be altered [31]. Therefore it is important to have a large mechanism design where users on the network can vote to for example reset the contract. A real world example is the Decentralized Autonomous Organization (DAO) hack in 2016, in which attackers exploited a flaw in a smart contract governing a decentralized investment fund. The incident led to the theft of over $60 million in Ether [2].

In blockchain, a distinction can also be made between fungible and non-fungible tokens (NFTs) [55]. Fungible tokens are tokens in which each unit is the same as any other unit of the same category, possessing equivalent value. For example, one five-pound note is the same as any other five-pound note. They can be used for fractional ownership and easier trading of standardized units of a commodity, which allows for simpler investment and trading in smaller amounts. Examples like Pax Gold, which is a digital token where one token represents one fine troy ounce of a London Good Delivery gold bar, stored in professional vaults in London [10]. On the contrary, NFTs are unique digital assets stored on a blockchain, meaning each NFT is distinct and cannot be directly replaced by another [7]. NFTs are used to tokenize assets that are unique, require individual identification, or where the provenance and history of a specific item are important [26].

In essence, the choice between using fungible or NFTs for tokenization depends fundamentally on the nature of the underlying asset and the desired characteristics of the digital representation. Before examining fraud risks in tokenized commodity platforms, it is important to first understand how traditional commodity markets work. This provides a foundation for comparison by highlighting how fraud has historically emerged and been addressed in conventional systems. The following section will discuss how physical commodity trading works.

3.2 Traditional Commodity Markets

In traditional commodity markets individuals can buy, sell, and trade commodities. These markets can be split into spot markets and futures and derivatives markets. In spot markets, transactions occur for immediate delivery of goods, and prices are determined based on real-time supply and demand. On the other hand, futures and derivatives markets involve contracts for delivery at a future date, where prices are influenced by speculation, hedging activities, and broader economic indicators [43]. Within the broader category of traditional commodity markets, precious metals are a significant group, including gold, silver, platinum, and palladium [25].

For futures markets, the main entity responsible for managing counterparty risk and ensuring transaction integrity is the clearinghouse [43]. The clearinghouse acts as a middleman making sure that both sides of the transaction meet their obligations by requiring initial margin deposits and daily settlement adjustments. It takes on counterparty risk, making trading more secure. In most futures markets, physical delivery is technically possible, but the majority of contracts are settled financially. Clearinghouses typically manage only the financial obligations such as margin requirements, rather than overseeing the delivery of physical commodities. When it comes to physical commodities in the supply chain, the issues of storage facilities and the responsibility during the transportation are presented, and the banks' involvement in financing and securing the physical trades are also discussed. However, these relate to the physical market, not typically the derivatives trading done by individual investors [25].

Governments and financial regulators provide strict oversight for commodity futures markets[38, 50]. Institutions like the Commodity Futures Trading Commission (CFTC) in the US, the Securities and Exchange Board of India (SEBI) in India oversee market practices, and the European Securities and Markets Authority (ESMA). Their roles include designing regulations, protecting investors, ensuring transparency, preventing market manipulation, enforcing contract obligations, and monitoring activities. Regulatory institutions enforce measures like position limits and reporting requirements, and use surveillance systems to prevent manipulation [15, 19].

3.3 Fraud Risks in Asset Markets

This paper defines fraud as intentionally deceiving individuals for personal gain or benefit. Fraud schemes often use false and/or deceptive representations to convince individuals to make payments, or engaging in accounting schemes designed to deceive others about a companies real situation through the manipulation of financial data. Manipulation, like market power manipulation, is considered a form of fraud because it relies on stealth and concealment, while information-based manipulation uses false or misleading statements [17, 38].

Fraud risks are a significant concern in asset markets, particularly in the context of commodity trading, largely due to the structural complexity of these markets and the challenges of verifying physical assets and transactions [38]. Commodities fraud typically involves the sale of a commodity through illicit means, such as deceptive marketing or manipulation in futures or options trading, where offenders may falsely promise high returns with little or no risk [17]. Unlike simple scams or false advertising, these schemes often exploit legitimate trading frameworks and rely on forged documentation or falsified collateral.

3.4 Tokenized Commodity Platforms

An important design element for tokenization platforms is the type of blockchain used for issuing, storing, and transacting the crypto tokens. Public blockchains offer transparency and decentralization by allowing anyone to verify transactions, while private blockchains restrict access to approved participants, offering more control but requiring greater trust in the central authority. [3]. For tokenizations referencing other on-chain crypto-assets, smart contracts can be used to provide custody and valuation assessments. However, tokenizations involving physical/off-chain real-world assets generally require an off-chain agent, such as a bank or auditor, to assess the value and provide custodial services [44, 48]. Many tokenization platforms also have a mechanism for redemption, allowing the holders to exchange tokens with the issuer for the real-world assets [9].

For example, Pax Gold offers a blockchain-based platform to digitize physical gold into tradable digital tokens [10]. This platform provides a secure and transparent way for investors to own gold via tokenization, aiming to overcome traditional storage and transaction challenges associated with physical gold. Pax Gold reportedly works with partners to ensure tokens are backed by physical gold in secure facilities. Tokenization can make it easier for owners to sell or exchange their fractionalized assets or use them as collateral for loans [9]. It is noted that modern gold-related tokenization projects may use a simple token creation method and might not fully account for asset management [20].

3.5 Regulatory and Technical Challenges

As we discussed before, regulators are also stakeholders of the commodity markets. Despite the potential benefits of tokenization, such as enhanced liquidity and democratizing access to investments, tokenized commodity platforms face several challenges.

A primary challenge is legal and regulatory uncertainty [48]. More specific, legal classification of tokenized assets remains unclear in many jurisdictions. This uncertainty impacts concrete asset ownership, what happens if the underlying asset is stolen or damaged, and who is responsible for storage and insurance. Determining jurisdiction for cross-border token holdings and asset storage is also an issue [52]. A token transfer between two users who live under different regulations can raise problems. Regulatory frameworks vary, affecting licensing, investor protection, and anti-money-laundering (AML) requirements. For example, the EU has introduced MiCa which is a regulation for crypto-assets. It covers issuance, offering, and trading of crypto-assets. It applies to asset-referenced tokens such as commodities, fiat-currencies or even a basket of different assets [16].

Next to that, tokenized markets are vulnerable to security issues [48]. The blockchain's attack surface is extensive, spanning data, network, consensus, smart contract, and application layers [44]. All these layers can have their own risks and issues. Risks specifically arise from the consensus, smart contract, and application layers. Thus, tokenized assets on blockchain networks are susceptible to hacking, phishing, and other cybercrimes. Because blockchain records are immutable, meaning that they cannot be altered or deleted, it promotes transparency. However it also introduces rigidity that limits the ability to address fraud and manipulation. Dependencies on trusted custodians pose risks if these entities encounter financial instability or fraud. Market manipulation, potentially amplified by algorithmic trading, is another risk. Building and maintaining trust in tokenized markets is complex and contingent on factors like blockchain security, smart contract quality, and the regulatory environment.

Decentralization can lead to trust dilemmas due to the gaps in the jurisdictions [48]. Without intermediaries, resolving transaction disputes, errors, or smart contract failures becomes more difficult as there is no central body to mediate or reverse issues [55]. Decentralized platforms may lack established mechanisms for dispute resolution. Fragmented decentralized governance models can hinder the efficient management of systemic risks, such as market manipulation or fraud. Robust regulatory frameworks are needed to prevent misuse and ensure accountability. The shift from traditional gatekeepers to a decentralized system fundamentally alters market dynamics.

Lastly, implementing tokenization requires businesses to find reliable technical enablers, financial partners, and legal advisors knowledgeable in blockchain, smart contracts, and digital tokens [44]. Compliance with frameworks such as Anti-Money Laundering (AML), Know Your Customer (KYC), and MiFID can be expensive. Blockchains used for tokenization may face challenges related to implementation costs, storage capacity, performance, and scalability [3]. Smart contracts have limitations, such as efficiency gains not being guaranteed in sectors without standardized contractual terms and complex legal principles not being easily translatable into digital form [55]. Ensuring smart contracts are developed in a standardized and consistent manner is also a challenge. Furthermore, projects often require infrastructure like depositories, suppliers, bank accounts, connections to exchanges, compliance officers, APIs, and client applications [20]. There is also a lack of fundamental development regarding how asset management should operate within tokenized systems.

4 METHODOLOGY

This study uses a **Systematic Literature Review (SLR)** as its research method. Scopus was chosen as the primary database for this SLR as it is among the most reliable and suitable databases for conducting systematic reviews due to its high recall, coverage, and export functionality [24]. Scopus also has an advanced search functionality which was used to construct three targeted search queries based on the study's research questions. The resulting queries are outlined below:

- **Query 1:** `TITLE-ABS-KEY( ( "asset tokenization" OR "tokenized asset*" OR "tokenized commodity" OR (asset AND tokeniz*) ) AND (fraud* OR manipul*) OR "asset tokenization" OR "tokenized asset*" OR "tokenized commodity" OR (asset AND tokeniz*) )`
  Focus: Literature addressing fraud risks in tokenized asset markets.
- **Query 2:** `TITLE-ABS-KEY( ("commodity market*" OR "physical commodity" OR "futures market*" OR "commodity trading") AND (fraud* OR manipul* OR "insider trading" OR spoofing OR misrepresent* OR "market abuse" OR scam* OR "warehouse receipt") )`
  Focus: Studies of fraud and manipulation in traditional commodity markets.
- **Query 3:** `TITLE-ABS-KEY( ("tokenized asset*" OR "asset tokenization" OR "tokenized commodity" OR (asset AND tokeniz*)) AND (regulation OR compliance OR "legal framework*" OR audit OR custody OR "technical safeguard*" OR AML OR KYC OR "smart contract*") )`
  Focus: Research on legal and technical safeguards in tokenized asset systems.

Each of the three queries was designed to emphasize a different dimension of the topic: fraud in tokenization (Query 1), safeguards and regulatory frameworks (Query 3), and traditional commodity market fraud (Query 2). Given the conceptual overlap between fraud and safeguards in tokenized assets, a significant number of papers were retrieved by both Query 1 and Query 3.

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria
Papers published from 2010 onward.
Papers published as journal articles, conference papers, reviews, or regulatory reports.
Papers written in English.
Papers that address at least one of the following: (1) fraud types in commodity markets or tokenized assets, (2) legal or technical safeguards in tokenized assets, or (3) issues of custody, manipulation, or compliance in tokenized systems.
Full-text availability.
Exclusion Criteria
Papers with low quality title and abstract
Papers focused solely on cryptocurrencies, DeFi, or NFTs without a link to tokenization or fraud.
Technical papers on smart contract languages or blockchain protocols with no discussion of safeguards or fraud.
Papers for which the full text was not accessible or paywalled without institutional access.

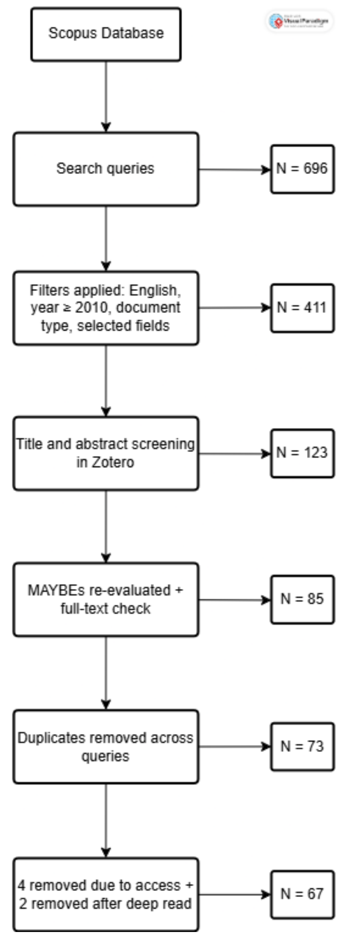

Fig. 1. Systematic Literature Review Article Selection Process

This was expected and is consistent with systematic review practices, where broad yet targeted queries are preferred to avoid missing relevant studies [24].

The initial search resulted in 696 papers which consists of 344 from the first query, 190 from the second, and 162 from the third. The results were filtered by language, selecting only English; by publication type, including journal articles, conference papers, and reviews; by publication year, selecting works published from 2010 onward; and by subject areas relevant to "Social Sciences", "Decision Sciences", "Computer Science", "Economics, Econometrics and Finance", and "Business, Management and Accounting". This resulted in 411 documents. Next, documents were classified in Zotero based on the title and abstract. 69 papers were classified as `YES`, 54 as `MAYBE`, and 288 as `NO`, leading to 123 documents. The documents in the `MAYBE` group were then again evaluated. Of these, 16 were reassigned to `YES`, resulting in a total of 85 papers marked for inclusion. At this point, 12 duplicates that overlapped between Query 1 and Query 3 were identified and removed, reducing the total to 73.

Finally, 4 papers were excluded due to public access limitations of the document and 2 were removed after careful reading. This yielded a final set of **67 papers** included in the systematic review. Because tokenization is a relatively new field, the published literature on tokenized commodities and fraud is extremely limited. The SLR therefore supports widening the search (Query 1) to include related work, such as tokenization of other assets so that all relevant insights are captured. Under fraudulent schemes, occurrences include collateral misrepresentation and double pledging, fictitious or duplicate asset tokenization, warehouse receipt fraud, and the use of falsified documentation, see Figure 2.

Each of the SRQs and their hypotheses are addressed with the search queries. SRQ1 and H1 are explored through the papers resulted from Query 1 and 2, which analyze fraud in commodity markets. SRQ2, together with H2 and H3, is explored using literature primarily from Query 3, which focuses on the legal and technical safeguards in tokenized commodity markets. The main RQ, together with H0, is addressed by synthesizing insights from all three queries, to evaluate to what extent tokenized commodity platforms address fraud-related risks.

5 LITERATURE REVIEW RESULTS

The systematic literature review identified several forms of fraud common in commodity markets such as market manipulation, insider trading, and various financing schemes. It also examined how these might represent itself in tokenized commodity platforms. Lastly, it explored how tokenization platforms attempt to mitigate these risks through blockchain technology and through regulatory measures.

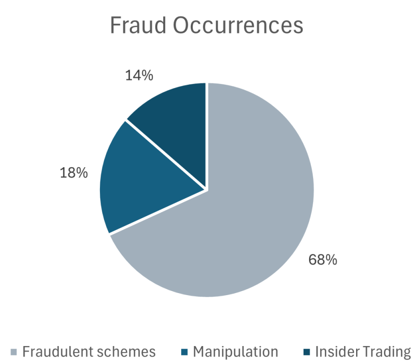

Fig. 2. Fraud Occurrences in SLR

5.1 Types of Fraud in Tokenized and Traditional Commodity Markets

Market manipulation has long been a form of fraud in commodity markets. Traditional commodities trading is prone to price manipulation schemes such as corners and squeezes, where a trader obtains market power over a commodity to distort its price [38]. For example, historical cases like the Hunt Brothers' silver corner in 1980 [13] or the Amaranth natural gas episode in 2006 [34] involved attempts to drive prices by monopolizing supply, raising questions of manipulation. Next to this type of manipulation, traders may engage in trade-based manipulation tactics. For example, an individual places large trades at settlement to sway closing prices. Also information-based manipulation, such as spreading false rumors to influence commodity prices. Pirrong categorizes commodity manipulation into these three types: (1) exercises of market power, (2) trade-based strategies, and (3) information-based manipulation [38].

Apart from market manipulation, commodity markets have witnessed insider trading and information abuse. Commodities have historically had looser insider trading restrictions than equities. This is because such markets are designed for hedging against risks like price fluctuations, and hedging decisions are often based on non-public information that can influence commodity prices, making it difficult to effectively ban this type of insider trading [41]. Verstein (2016) even notes that in securities markets, insider trading is a crime but in commodities, insider trading is almost completely legal [50]. Verstein also argues that the justifications for treating commodities differently than securities "do not withstand serious scrutiny" and that insider trading is comparably harmful in commodities, calling for equal restrictions. Tokenized markets can also be victim to insider trading, because many tokens are being listed and traded on smaller exchanges or Decentralized Exchanges (DEXs) while there are no strict regulations [5, 8, 54]. Non-public information like upcoming listings or partnerships can influence the price positively or negatively. If individuals are aware of this information, it is unfair towards other market participants as insiders could trade those tokens for near-guaranteed profit. The insider information would likely be the same in the case of tokenization of commodities, since the underlying asset is a commodity. Thus, without clear regulations, tokenized commodity markets are likely to suffer from the same insider trading behavior.

Commodity markets are also plagued by fraudulent schemes in financing and trading operations. An example took place in China's metals markets from 2009 to 2014. Massive shadow-financing deals using metal stockpiles as collateral led to a web of deceit. The lack of transparency in China's commodity collateral financing market not only incentivized widespread fraud but also revealed how such opacity can pose significant risks to the stability of global metal markets. Another example for this is the 2014 Qingdao Port scandal [14], where the trading firm Dezheng Resources used the same stock of aluminum and copper to obtain multiple warehouse receipts and pledged them to several banks, securing multiple loans on the same collateral. This type of warehouse receipt fraud, involving the multiple pledging of the same collateral, went unnoticed until the scheme collapsed, resulting in significant losses for several creditors. This event led people to lose trust in storage networks. These cases illustrate how opaque, incomplete regulations on commodity exchanges can become breeding grounds for fraud.

Another scheme was India's NSEL scandal (2013) [42], where an electronic spot commodity exchange defaulted on $1.3 billion after it was revealed that most trades were fictitious. NSEL had offered paired contracts promising fixed returns while bypassing regulators, eventually collapsing in a payment crisis. Deeper investigations showed signs that some contracts were also executed on duplicate warehouse receipts.

These cases illustrate how opaque and poorly regulated commodity markets can become breeding grounds for fraud. In both examples, fraudsters took advantage of information asymmetry and

Type of Fraud	Description	Sources for Further Reading
Manipulation	Intentionally artificially influencing prices to deceive investors. Common techniques include market power, trade-based manipulation, and spreading false information to affect price movement.	[13, 34, 38]
Insider Trading	Trading based on material non-public information, often in environments with weak enforcement. Particularly relevant in smaller exchanges and decentralized platforms.	[41, 50]
Fraudulent Schemes	Misrepresentation of asset backing, financial misreporting, falsification of documentation, and repeated pledging of the same collateral. Includes warehouse receipt fraud and forged inventory claims.	[14, 42]

Table 2. Types of Fraud in Traditional Commodity Markets

regulatory gaps. Similar problems could also occur in tokenized commodity markets if proper mechanisms and safeguards are not in place. If there is a lack of oversight on the physical commodities, individuals can for example try to tokenize commodities that do not exist. Essentially, without regulation and transparency of proper checks, an individual could digitally represent the same commodity stock multiple times.

5.2 Technical and Legal Safeguards in Tokenized Commodity Markets

Existing tokenization platforms are designed with features intended to mitigate fraud risks, yet the literature suggests they only partially address these risks. Every transfer of a token representing a commodity is recorded on a distributed ledger which is visible on the network, making it extremely difficult to alter or forge transaction history. This transparency can deter tampering and enable quicker detection of anomalies. For example, a blockchain-based registry provides transparency and traceability of digital assets from the first transaction through all subsequent ones, thereby increasing trust in the asset [12]. This can also make fraud like double-selling much harder. Additionally, smart contracts offer automated enforcement of rules and contractual terms. They can be programmed to check conditions such as payment receipt, delivery confirmation, or regulatory clearance before allowing a token transfer, which helps prevent fraudulent or non-compliant transactions. For example, compliance frameworks for security tokens require that only verified, KYC-approved addresses can hold or trade certain asset tokens. On the other hand, someone could still attempt fraud by inputting false information onto the blockchain, for example by tokenizing a nonexistent asset. This is why smart contracts themselves should also be properly secured and audited, because you do not want to have tokenized commodities without an actual underlying stock in smart contracts.

This issue can be mitigated by another technical safeguard, which is the use of oracles and Internet of Things (IoT) integrations to bridge the physical world with the digital world [6]. This bridge is quite important since it can also be susceptible to fraud like misrepresentation of assets, as mentioned before. Because blockchain itself cannot verify real-world events, tokenized commodity systems often employ oracles, which are trusted data feeds or sensor integrations, to confirm that a physical commodity is indeed in a warehouse, of a certain quality, and not double-counted before minting or transferring tokens. Physical assets can be tagged with these IoT devices and connect them together with oracles to the blockchain. However, the effectiveness of these measures varies. The literature acknowledges that it is challenging to absolutely guarantee a single, unique matching between a physical asset and the token [1, 18, 21, 32]. While storing detailed asset information on-chain enables public verification of the link between physical and digital, the store and verification of all relevant information to bind each asset to a specific token is a complex process for physical assets. That is why tokenization platforms, next to IoT devices and oracles, use auditors and third-party audits of reserves by a an authorized auditor, which is trusted information and can be put on-chain through oracles [11].

An interesting example is BlockPAT, a system that tokenizes second-hand physical assets into NFTs to enable transparent ownership tracking and automated pricing using oracles [51]. On the other hand, in June 2019, a malfunctioning oracle on the Synthetic platform misreported prices, leading to the trade of 37 million synthetic ether (sETH) at low rates and causing nearly one billion dollars in impact [11]. This is also known as the oracle problem, the challenge of securely and reliably integrating external data into a decentralized system. In real estate for example, retail banks could act as the oracle. They can assure that the real-world data is accurate [29]. For commodities banks or auditors could also act as the oracle to ensure accurate data. An interesting case could also be using multiple independent and requiring a consensus among them.

Next to technical safeguards, a number of legal and regulatory measures are being applied or developed to govern tokenized commodity markets, aiming to protect against fraud [30]. These legal frameworks and jurisdictions are needed to develop some standard, protect consumers and ensure safe practices. However, responses from regulators vary across jurisdictions [48]. For instance, many jurisdictions have started integrating asset tokenization into existing financial and securities frameworks to prevent misuse and ensure clarity of legal obligations. For example, if a gold-backed token is deemed a security, the issuer must comply with securities laws like MiFID II, which are designed to prevent fraudulent offerings and misrepresentation [27]. This is because there are no specific regulations yet for each type of tokenized asset, in this case commodities [22]. On the other hand, the European Union's MiCA regulation and Switzerland's Financial Services Act (FINSA) try to classify digital tokens and ensure investor protection through disclosure, auditability, and issuer accountability [54]. However, Zhang et al. compared seven big economies and note a concern: without a clear and consistent legal framework, tokenization platforms can encounter more fraudulent activities.

Safeguard Type	Description	Sources for Further Reading
Distributed Ledger	Decentralized system that records transactions in a tamper-resistant, transparent, and immutable manner. Consensus system with each node having a copy reduces unauthorized alterations to transaction history.	[45, 49]
Smart Contracts	Code that executes when certain programmable conditions are met. For example, regulatory rules can be programmed.	[37, 39, 47]
Oracles	Oracles connect blockchains to external real-world information, such as asset prices or warehouse audits. They help validate the physical existence and condition of tokenized assets.	[6, 29]
IoT Integration	Physical tagging and sensor-based tracking of physical assets to ensure accurate linkage. Enhances auditability and reduces misrepresentation risk.	[1, 6, 18]
Auditing	Third-party or automated verification of reserves and asset status, often tied to token issuance or redemption. Helps verify that tokenized assets are genuinely backed.	[10]
MiCA Regulation	The EU's Markets in Crypto-Assets (MiCA) regulation sets out rules for asset-referenced tokens, including issuer disclosure, investor protection, and platform accountability.	[16]
Regulatory Sandboxes	Controlled environments set up by regulators that allow tokenization platforms to test their projects, under temporary regulatory relief. They support innovation while maintaining oversight and help identify necessary legal adaptations.	[40, 54]
Jurisdictional Securities Laws	Financial regulators like FINMA and SEC that classify and regulate financial products, like tokenized commodities, under existing or new financial regulations.	[5, 23, 27, 35]

Table 3. Legal and Technical Safeguards in Tokenized Commodity Markets

In addition, the EU takes a more pragmatic view than Switzerland. In Switzerland, banks and institutions can already hold DLT securities tokens [22]. Next to that, they are also consistently updating their laws related to asset tokenization. Consequently, this uneven regulatory landscape can mean that fraud can occur more in weaker regimes, which points to the need for stronger regulations. Furthermore, since the field of tokenization is in its early stages, new jurisdictions and frameworks arise, like FCToken which is a blockchain framework compliant tokenization with on-chain identity and customizable tokens [47]. Next to upcoming frameworks and jurisdictions, countries like the UK, Australia and South-Korea allow firms to test their tokenization projects in sandboxes, which are controlled environments. Referring back to the cross-jurisdictional challenge noted in the background, what if a transfer of tokens happens from users that live under different regulations? For example, in the United States tokenized real-estate tokens fall under securities and must comply with the Securities and Exchange Commission (SEC) regulations. In contrast, in Switzerland these real-estate tokens also fall under securities and must comply with Swiss Financial Market Supervisory Authority (FINMA) regulations [35]. Therefore, these jurisdictional differences can lead to legal ambiguity, especially regarding investor rights and taxes.

Although no globally harmonized regulatory regime has been found in the literature, several jurisdictions have begun crafting targeted legal frameworks to address the unique risks and features of tokenized assets. The regulatory designation of a tokenized commodity is also based on its design; if it incorporates aspects such as profit-sharing, dependence on third parties, or investment traits, it could be classified as a security even though it is backed by a commodity. The issuer of the token The EU's MiCA regulation [16], Switzerland's DLT Act [22], Liechtenstein's Blockchain Act [5], and Germany's electronic securities legislation [27] are examples. These initiatives aim to close regulatory gaps by recognizing tokenized representations of assets under existing or adapted traditional financial law. Regulators like ESMA, FINMA and SEC remain concerned about fraud and market integrity in token markets, stressing that the evolution of asset tokenization necessitates continued regulatory attention [28]. While there aren't specific regulations for tokenized commodities, the MiCA regulation is relevant when these tokens are classified as asset-referenced tokens (ARTs). This encompasses tokens supported by commodities such as gold, as long as they intend to uphold a stable value. Platforms issuing such tokens to the public must comply with MiCA's requirements, including authorization and disclosure, as well as AML, KYC, custody, and capital standards [16, 30].

6 DISCUSSION

Main RQ: The SLR shows that existing tokenized commodity platforms partially address but do not eliminate fraud risks. In response to the Main RQ, blockchain features like immutability and transparency can deter certain traditional frauds, for example falsified records or double-selling. However, a vulnerability still remains between the digital tokens and the physical commodities, because blockchain cannot inherently verify off-chain assets. Therefore, fraud like misrepresentation is still possible without trusted oracles and audits. As predicted by H0 and supported by the literature, platforms increase traceability but only partially reduce fraud.

SRQ1 (Fraud types): The SLR validates that the frauds detected in traditional commodity markets continue to exist, supporting H1. Various sources show that market manipulation, insider trading, and collateral misrepresentation as the most prevalent types of fraud. For example, classic cases like Hunt Brothers in silver and Amaranth in natural gas illustrate the ease of price manipulation by controlling supply. Insider trading is noted as rampant in less-regulated commodity exchanges. Likewise, complex schemes like China's Qingdao warehouse fraud show how opaque collateral financing and duplicate warehouse receipts enable massive misrepresentation.

SRQ2 (Safeguards): Tokenized platforms use different technical and legal measures (Table 3) to prevent fraud. From a technical perspective, distributed ledgers and smart contracts improve transparency and automatically implement regulations. For example, public records complicate the modification of transaction histories, and contracts can automatically mandate KYC/AML prior to transfers. However, these measures depend on accurate real-world data. The incorporation of oracles and IoT connections aims to associate physical assets with tokens. However, the literature indicates that these connections create new attack surfaces. Defective oracles (similar to the 2019 Synthetic platform case) can enable fraud on their own. To put it differently, H2 is supported: Blockchain immutability and smart contracts enhance traceability and automate compliance; however, they also introduce vulnerabilities related to data inputs and the accuracy of code.

Legally, platforms are governed by a diverse mix of regulations. The upcoming MiCA regulation from the EU and individual country laws seek to address shortcomings. Nevertheless, we did not discover a cohesive international structure. This affirms H3: regulatory fragmentation continues to be a significant obstacle. In reality, inconsistent definitions may lead to gaps or uncertainty. One nation designates a commodity token as a security, while another regards it as a commodity. A token sale may adhere to regulations in one area while violating them in another, which weakens fraud prevention.

7 LIMITATIONS

Initially the research design also included an interview from an industry expert. Despite reaching out to several industry experts, they either did not respond or declined participation. Consequently, the findings are shaped by the available literature, which is conceptual and theoretical and is still emerging in the area of tokenized commodities and often lacks empirical validation. Secondly, the scope of the review is constrained by the use of a single database (Scopus), which may have excluded relevant studies found elsewhere. Third, there is no risk-of-bias assessment or quality scoring of the included papers, which may affect the strength of the conclusions. Finally, the synthesis is limited by the descriptive nature and overlap of many included sources, which makes it difficult to assess the effectiveness of specific safeguards in directly preventing fraud.

8 FUTURE WORK

Most importantly, further empirical studies are necessary, including expert interviews or case analyses, to offer practical understanding of the operation of tokenization platforms and the dynamics of fraud and protective measures in actual scenarios. This would assist in confirming or questioning assumptions in the literature, provide practical insights into operational risks, and aid in creating more efficient regulatory and technical structures.

Secondly, IoT devices and oracles were mentioned in the literature, which can be very interesting in combination with the uprise of artificial intelligence (AI). Future studies could look deeper into the integration of IoT devices and oracles together with AI to prevent for example misrepresentation. The combination of these growing fields may enhance automation and trustworthiness. This is relevant because combining these two can improve the accuracy and reliability of RWA verification and can prevent fraud in misrepresentation, which is one of the key challenges in tokenization.

9 CONCLUSION

This research investigated how tokenized commodity platforms manage risks associated with fraud. The results indicate that conventional fraud categories like market manipulation, insider trading, and misrepresentation of collateral are still common, whereas tokenization brings forth new risks like bugs in smart contracts and manipulation of oracles. While technical measures such as smart contracts and oracles improve transparency, they rely on reliable off-chain information. Legally, inconsistent and fragmented regulations obstruct efficient fraud prevention, particularly across different jurisdictions. In general, although tokenization enhances traceability, it is not a solution for every problem. Ongoing information disparities and regulatory shortcomings remain problematic. Nevertheless, because of the dominance of conceptual and theoretical studies, the practical efficacy of numerous safeguards is still unclear.

REFERENCES

[1] Aleksandar Arnautović, Marijana Despotović Zrakić, and Zorica Bogdanović. 2025. Innovating Real Estate Business Models with Blockchain. In *Proceedings of the 24th International Symposium INFOTEH-JAHORINA*. IEEE, 1–8. https://doi.org/10.1109/INFOTEH64129.2025.10959232

[2] Nicola Atzei, Massimo Bartoletti, and Tiziana Cimoli. 2017. A survey of attacks on Ethereum smart contracts (SoK). In *International Conference on Principles of Security and Trust*. Springer, Berlin, Heidelberg, 164–186.

[3] M. Baltais, E. Sondore, T. J. Putniņša, and J. R. Karlsen. 2024. *Economic impact potential of real-world asset tokenization.* Report 2024-06. UTS Business School, University of Technology Sydney.

[4] T. Barbereau, J. Sedlmeir, R. Smethurst, G. Fridgen, and A. Rieger. 2022. Tokenization and Regulatory Compliance for Art and Collectibles Markets: From Regulators' Demands for Transparency to Investors' Demands for Privacy. In *Blockchains and the Token Economy: Theory and Practice*. Springer International Publishing, Cham, 213–236.

[5] Andrew Baum. 2021. Tokenization—The Future of Real Estate Investment. *Journal of Property Investment & Finance* 39, 4 (2021), 337–341. https://doi.org/10.1108/JPIF-06-2021-0062

[6] Abdeljalil Beniiche, Sajjad Rostami, and Martin Maier. 2022. Society 5.0: Internet as if People Mattered. *IEEE Wireless Communications* 29, 6 (2022), 160–168. https://doi.org/10.1109/MWC.009.2100570

[7] T. Bhandare and M. A. Kandi. 2024. Tokenization of Fine Arts: Revolutionizing the Fine Arts Industry with Blockchain. In *Blockchain and Smart-Contract Technologies for Innovative Applications*. Springer Nature Switzerland, Cham, 167–187.

[8] Stéphane Blemus and Dominique Guégan. 2020. *Initial Crypto-asset Offerings (ICOs), tokenization and corporate governance.* Documents de Travail 2019.04. Centre d'Economie de la Sorbonne. https://centredeconomiesorbonne.univ-paris1.fr/ ISSN : 1955-611X.

[9] Francesca Carapella, Nathan Swem, and Joshua Gerszten. 2023. *Tokenization: Overview and Financial Stability Implications.* Technical Report 2023-077. Board of Governors of the Federal Reserve System (U.S.). https://doi.org/10.17016/FEDS.2023.077

[10] Charles Cascarilla. 2019. Paxos Pax Gold (PAXG): White Paper. https://www.paxos.com/pax-gold-whitepaper. Last updated September 5, 2019.

[11] Yudong Chen, Jinyuan Wu, Haoyu Zhu, Zhen Feng, Xinyu Lu, and Haoyu Liu. 2024. Exploring the Security Issues of Real World Assets (RWA). *arXiv preprint* (2024). arXiv:2401.11694 [cs.CR] https://arxiv.org/abs/2401.11694

[12] Isaac Coffie and Martin Saint. 2021. Digitizing Physical Assets on Blockchain 2.0: A Smart Contract Approach to Land Transfer and Registry. In *Towards New e-Infrastructure and e-Services for Developing Countries: Proceedings of the 12th EAI International Conference, AFRICOMM 2020, Ebène City, Mauritius, December 2–4, 2020*, R. Zitouni et al. (Eds.). Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, Vol. 361. Springer Nature Switzerland AG, 234–252. https://doi.org/10.1007/978-3-030-70572-5_15

[13] Mark Crain, Robert McDonald, and Rex Thompson. 2020. Fixing the Fix for Silver and Gold. *The Journal of Alternative Investments* 23, 3 (2020), 79–94. https://doi.org/10.3905/jai.2020.1.096

[14] J. Engel. 2020. Regulation, financialization and fraud in Chinese commodity markets after the Global Financial Crisis. *Regional Studies* 54, 2 (2020), 219–228.

[15] European Securities and Markets Authority (ESMA). 2017. The Distributed Ledger Technology Applied to Securities Markets. https://www.esma.europa.eu/sites/default/files/library/esma50-1121423017-285.pdf. Accessed June 2025.

[16] European Union. 2023. Regulation (EU) 2023/1114 of the European Parliament and of the Council of 31 May 2023 on Markets in Crypto-assets, and amending Regulations (EU) No 1093/2010, (EU) No 1094/2010 and (EU) No 1095/2010. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023R1114. Official Journal of the European Union, L 150, 9.6.2023, p. 40–207.

[17] Federal Bureau of Investigation. 2011. *Financial Crimes Report to the Public: Fiscal Years 2010–2011*. Technical Report. U.S. Department of Justice, Criminal Investigative Division, Washington, D.C. https://www.fbi.gov/stats-services/publications/financial-crimes-report-to-the-public-2010-2011 Accessed via archived FBI report.

[18] Giuseppe Ferrara, Fabrizio Messina, Massimiliano De Benedetti, and Corrado Santoro. 2022. Physical Assets Tokenization for Blockchain Market. In *Intelligent Distributed Computing XIV*, David Camacho et al. (Eds.). Studies in Computational Intelligence, Vol. 1026. Springer Nature Switzerland AG, 273–282. https://doi.org/10.1007/978-3-030-96627-0_25

[19] FICC Markets Standards Board. 2021. *Precious Metals Market Structure: Spotlight Review*. Technical Report. FICC Markets Standards Board Limited. https://fmsb.com Spotlight Review.

[20] V. N. Frolov, A. A. Vatolin, and A. P. Romanchuk. 2023. Asset tokenization and related problems. *Proceedings of the Steklov Institute of Mathematics* 323, Suppl 1 (2023), S98–S112.

[21] Rosa M. Garcia-Teruel and Helena Simón-Moreno. 2021. The Digital Tokenization of Property Rights: A Comparative Perspective. *Computer Law Security Review* 41 (2021), 105535. https://doi.org/10.1016/j.clsr.2021.105535

[22] Maria Girich, Ivan Ermokhin, and Antonina Levashenko. 2022. Comparative Analysis of the Legal Regulation of Digital Financial Assets in Russia and Other Countries. *International Organisations Research Journal* 17, 4 (2022), 176–192. https://doi.org/10.17323/1996-7845-2022-04-07

[23] A. Gupta, J. Rathod, D. Patel, J. Bothra, S. Shanbhag, and T. Bhalerao. 2020. Tokenization of Real Estate Using Blockchain Technology. In *Applied Cryptography and Network Security Workshops: ACNS 2020 Satellite Workshops, AIBlock, AIHWS, AIoTS, Cloud S&P, SCI, SecMT, and SiMLA, Rome, Italy, October 19–22, 2020, Proceedings 18*. Springer International Publishing, 77–90.

[24] Markus Gusenbauer and Neal R. Haddaway. 2020. Which academic search systems are suitable for systematic reviews? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. *Research Synthesis Methods* 11, 2 (2020), 181–213. https://doi.org/10.1002/jrsm.1378

[25] Murad Harasheh. 2021. *Global Commodities: Physical, Financial, and Sustainability Aspects*. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-030-64026-2

[26] R. Heines, C. Dick, C. Pohle, and R. Jung. 2021. The Tokenization of Everything: Towards a Framework for Understanding the Potentials of Tokenized Assets. In *Proceedings of the Pacific Asia Conference on Information Systems (PACIS)*. 40.

[27] Robert Henker, Daniel Atzberger, Willy Scheibel, and Jürgen Döllner. 2023. Real Estate Tokenization in Germany: Market Analysis and Concept of a Regulatory and Technical Solution. In *2023 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)*. IEEE, 1–8. https://doi.org/10.1109/ICBC56567.2023.10174954

[28] Nauris Jūrmalis, Anželika Berk e Berga, and Marta Urbāne. 2025. Advancing Asset Tokenization in the European Union and Latvia: A Regulatory and Policy Perspective. *Laws* 14, 1 (2025), 7. https://doi.org/10.3390/laws14010007

[29] Piotr Kasprzak. 2021. Blockchain to the Rescue—Tokenization of Residential Real Estate in the Emerging Token Economy. In *Digitalization, Digital Transformation and Sustainability in the Global Economy*, Tim Herberger and Jörn Dötsch (Eds.). Springer Nature Switzerland AG, 21–35. https://doi.org/10.1007/978-3-030-77340-3_3

[30] Mariusz Kiskis. 2024. Private Law Framework for Blockchain. *Computer Law & Security Review* 51 (2024), 105899. https://doi.org/10.1016/j.clsr.2023.105899

[31] Lukas König, Stefan Unger, Peter Kieseberg, and Simon Tjoa. 2020. The Risks of the Blockchain: A Review on Current Vulnerabilities and Attacks. *Journal of Internet Services and Information Security* 10, 3 (August 2020), 110–127. https://doi.org/10.22667/JISIS.2020.08.31.110

[32] Xavier Lavayssière. 2025. Legal Structures of Tokenised Assets. *European Journal of Risk Regulation* (2025), 1–13. https://doi.org/10.1017/err.2024.88 Open Access under CC BY 4.0.

[33] Michael Levi. 2009. Financial Crime. In *Oxford Handbook of Crime and Public Policy*, Michael Tonry (Ed.). Oxford University Press, New York, 223–246.

[34] John E. Marthinsen and Yunwei Gai. 2010. Did Amaranth's Absolute, Relative and Extreme Positions Affect Natural Gas Futures Prices, Spreads and Volatilities? *Journal of Derivatives & Hedge Funds* 16, 1 (2010), 9–21. https://doi.org/10.1057/jdhf.2010.3

[35] Seyedeh Fatemeh Mottaghi, Bertram I. Steininger, and Noriyuki Yanagawa. 2024. Real Estate Insights: The current state and the new future of tokenization in real estate. *Journal of Property Investment & Finance* 42, 6 (2024), 614–620. https://doi.org/10.1108/JPIF-07-2024-0087

[36] Satoshi Nakamoto. 2008. Bitcoin: A Peer-to-Peer Electronic Cash System. https://bitcoin.org/bitcoin.pdf. Accessed: 2025-05-03.

[37] Vedant Jayesh Oza, Atharva Nikte, Viral Bhanushali, and Uday Rote. 2024. Smart Contracts and Tokenization: Revolutionizing Real Estate Transactions with Blockchain Technology. In *Proceedings of the 7th International Conference on Inventive Computation Technologies (ICICT 2024)*. IEEE, 1598–1604. https://doi.org/10.1109/ICICT60155.2024.10544886

[38] Craig Pirrong. 2017. The economics of commodity market manipulation: A survey. *Journal of Commodity Markets* 5 (2017), 1–17.

[39] Nirav Pocha, Rushabh Shah, Yash Shah, and Pankaj Sonawane. 2023. Decentralized One Stop Solution for Real Estate. In *2023 International Conference on Advanced Computing Technologies and Applications (ICACTA)*. IEEE, 1–7. https://doi.org/10.1109/ICACTA58201.2023.10392709

[40] Hikmal Pramudya, Andry Alamsyah, and Dodie Tricahyono. 2024. Blockchain-Based Tokenization for Green Bonds: A Model for Transparency and Compliance in Sustainable Finance. In *2024 IEEE Asia-Pacific Conference on Geoscience, Electronics and Remote Sensing Technology (AGERS)*. IEEE, 64–69. https://doi.org/10.1109/AGERS65212.2024.10932908

[41] Willy-Anthony Rousse and Benoît Sévi. 2019. Informed Trading in the WTI Oil Futures Market. *Journal of Commodity Markets* 13 (2019), 1–18. https://doi.org/10.1016/j.jcomm.2018.11.001

[42] D. Satish and M.V. Nagendra Kumar. 2015. NSEL's Payment Crisis: Jolt to Indian Commodity Markets. *Asian Journal of Management Cases* 12, 2 (2015), 148–157. https://doi.org/10.1177/0972820115592211

[43] M. S. Sawant. Unknown Year. *Commodity Markets and Futures Trading: Basics and Operational Mechanisms*. Unknown Publisher.

[44] G. Sazandrishvili. 2020. Asset tokenization in plain English. *Journal of Corporate Accounting & Finance* 31, 2 (2020), 68–73.

[45] Romildo Silva, Helena Inácio, and Rui Pedro Marques. 2. Blockchain implications for auditing: a systematic literature review and bibliometric analysis. *The International Journal of Digital Accounting Research* 22 (2), 163–192.

[46] Manmeet Singh, Eliecer Fuenmayor, Eoghan P. Hinchy, Yijiao Qiao, Niall Murray, and Declan Devine. 2021. Digital twin: Origin to future. *Applied System Innovation* 4, 2 (2021), 36. https://doi.org/10.3390/asi4020036

[47] Hao Tan, Guanghuan Xie, Shuangzhou Yan, Hongxin Zhang, Xin Zou, and Zhuo Li. 2023. FCToken: A Flexible Framework for Blockchain-Based Compliance Tokenization. In *2023 IEEE International Conference on Data Mining Workshops (ICDMW)*. IEEE, 671–681. https://doi.org/10.1109/ICDMW60847.2023.00093

[48] U. Tanveer, S. Ishaq, and T. G. Hoang. 2025. Tokenized Assets in a Decentralized Economy: Balancing Efficiency, Value, and Risks. *International Journal of Production Economics* (2025), 109554. https://doi.org/10.1016/j.ijpe.2024.109554

[49] Oleksii Tonkykh, Viktoriia Derhachova, Svitlana Palii, Sergiy Bratushka, and Andrii Zolkover. 2023. Blockchain Technology and the Transformation of Financial Systems: From Decentralization to Innovative Solutions in the Global Economy. *Economic Affairs* 68, 4 (2023), 2221–2228. https://doi.org/10.46852/0424-2513.4.2023.30

[50] Andrew Verstein. 2016. Insider trading in commodities markets. *Virginia Law Review* 102 (2016), 447–514.

[51] Jiaxuan Wu, Wei-Yang Chiu, Weizhi Meng, and Brooke Lampe. 2023. BlockPAT: A Blockchain-Enabled Second-Hand Physical Asset Tokenization Management System. In *2023 IEEE 43rd International Conference on Distributed Computing Systems (ICDCS)*. IEEE, 1041–1042. https://doi.org/10.1109/ICDCS57875.2023.00135

[52] Ning Xia, Xiaolei Zhao, Yimin Yang, Yixuan Li, and Yucong Li. 2025. Exploration on Real World Assets and Tokenization. https://arxiv.org/abs/2503.01111. arXiv preprint arXiv:2503.01111.

[53] Dirk A. Zetzsche, Douglas W. Arner, and Ross P. Buckley. 2020. Decentralized finance. *Journal of Financial Regulation* 6, 2 (2020), 172–203.

[54] Ying Zhang, Bing Gong, and Peng Zhou. 2024. Centralized use of decentralized technology: Tokenization of currencies and assets. *Structural Change and Economic Dynamics* 71 (2024), 15–25. https://doi.org/10.1016/j.strueco.2024.06.006

[55] Minhao Zheng and Philipp Sandner. 2022. Asset tokenization of real estate in Europe. In *Blockchains and the Token Economy: Theory and Practice*. Springer International Publishing, Cham, 179–211. https://doi.org/10.1007/978-3-030-99974-7_10

A APPENDIX

During the preparation of this work the author used Grammarly and ChatGPT in order to improve the spelling and grammar of the writing. After using this tool/service, the author reviewed and edited the content as needed and take(s) full responsibility for the content of the work.

ACKNOWLEDGMENTS

I would like to thank my supervisor, Dr. F.S. Bernard, for his guidance, useful comments and feedback, and continued support throughout this research.

Author	Title	Analytical Notes	Fraud Discussed?	Legal Safeguards	Technical Safeguards
Barbuta et al. (2024)	A Secure Real Estate Transaction Framework Based on Blockchain Technology and Dynamic Non-Fungible Tokens	Ownership fraud, documents, framework addresses security, traceability, and ownership updates via smart contracts and oracles	Yes	No	Yes
Jurmalis et al. (2025)	Advancing Asset Tokenization in the European Union and Latvia: A Regulatory and Policy Perspective	Context for legal safeguards that would influence fraud exposure	No	Yes	No
Frolov et al. (2023)	Asset tokenization and related problems	Highly relevant for analyzing systemic vulnerabilities due to inadequate reserves and backing	No	Yes	Yes
Sazandrishvili et al. (2020)	Asset tokenization in plain English	Benefits tokenization, mentions steps for tokenization, asset-backed tokens, legal challenges	No	No	Yes
S et al. (2021)	Asset Tokenization: A Simulation Study	Nice table with aspects of tokenization concerning technology, quality, legal. Useful for structural understanding of token systems.	No	No	Yes
Lo et al. (2020)	Assets on the blockchain: An empirical study of Tokenomics	Exit scams and legal ambiguity in ICO-funded projects	Yes	Yes	Yes
Ross et al. (2019)	Assets under tokenization: Can blockchain technology improve post-trade processing?	Nice table with functions and mitigating factors and requirements, offering structural protection against fraud	Yes	Yes	Yes
Barger et al. (2023)	Atomyze - The Scalable Hyperledger Fabric-Powered Blockchain Platform Revolutionizing Asset-Backed Tokenization	Framework for specifically tokenizing commodities, describes security architecture and anti-fraud features in a tokenized commodity platform.	No	Yes	Yes
Silva et al. (2022)	Blockchain implications for auditing: a systematic literature review and bibliometric analysis	How blockchain enables fraud-resistant auditing through traceability	Yes	No	Yes
Macriga et al. (2024)	Blockchain Powered Real-Estate Management System	Steps for tokenizing property formatted in a table	No	No	Yes
Tonkykh et al. (2023)	Blockchain Technology and the Transformation of Financial Systems: From Decentralization to Innovative Solutions in the Global Economy	This paper is about blockchain adoption in financial markets. Also talks about solutions for problems like asset backing	No	Yes	No
Kasprzak et al. (2021)	Blockchain to the Rescue - Tokenization of Residential Real Estate in the Emerging Token Economy	Nice information about the use of oracles and the banks as trusted source, relevant for safeguarding against misrepresentation	No	Yes	Yes
Avci et al. (2023)	Blockchain tokenization of real estate investment: a security token offering procedure and legal design proposal	Fraud and information asymmetry, legal token design and smart contract usage that indirectly contributes to mitigating fraud risk.	Yes	Yes	Yes
Pramudya et al. (2024)	Blockchain-Based Tokenization for Green Bonds: A Model for Transparency and Compliance in Sustainable Finance	regulatory sandboxes, interesting for new developments, emphasizing transparency and compliance	No	Yes	Yes
Sinha et al. (2024)	Blockchain-Powered Asset Tokenization Platform	Decentralized platform for secure and compliant asset tokenization using smart contracts	No	No	Yes
Wu et al. (2023)	BlockPAT: A Blockchain-Enabled Second-Hand Physical Asset Tokenization Management System	System with steps on how to tokenize secondhand assets	No	No	Yes
Golding et al. (2022)	Carboncoin: Blockchain Tokenization of Carbon Emissions with ESG-based Reputation	Role of regulators on tokenization. Proposes on-chain ESG-based scoring for emission trading, addressing trust and transparency.	No	Yes	Yes
Wong et al. (2025)	CBDCs, regulated stablecoins and tokenized traditional assets under the Basel Committee rules on cryptoassets	Role of regulators on tokenization	No	Yes	No
Zhang et al. (2024)	Centralized use of decentralized technology: Tokenization of currencies and assets	Comparing 7 major economies on tokenization, mostly on regulations, sandbox example	Yes	Yes	Yes
Girich et al. (2022)	Comparative Analysis of the Legal Regulation of Digital Financial Assets in Russia and Other Countries	Analyzes legal frameworks for tokenized financial instruments across jurisdictions, MIFID	No	Yes	No
Geetha et al. (2024)	Creating Resilient Digital Asset Management Frameworks in Financial Operations Using Blockchain Technology	Digital asset system together with smart contracts. Reasons why adoption should take place within the financial realm	No	Yes	Yes
Dwivedi et al. (2023)	Cross-Chain Atomic Swaps without Time Locks	Protocol for secure asset exchange between blockchains	No	No	Yes
Pocha et al. (2023)	Decentralized one stop solution for real estate	Technical but can be handy for more technical insights to smart contract processes	No	No	Yes
Marthinsen et al. (2010)	Did amaranth advisors LLC engage in interday price manipulation in the natural gas futures market	Interesting case, investigates interday price manipulation in natural gas futures	Yes	Yes	No
Coffie et al. (2021)	Digitizing Physical Assets on Blockchain 2.0: A Smart Contract Approach to Land Transfer and Registry	The smart contract model proposed demonstrates how digitization can reduce transaction opacity and manual errors that may lead to fraud.	No	No	Yes
López-Pimentel et al. (2024)	Distributed software architecture for accessing the NFT-Vehicle	Case with a lot of information for the cycle of tokenized assets, fraud with info asymmetry	Yes	Yes	Yes
Silva et al. (2021)	Effective and Potential Implications of Blockchain Technology for Auditing	Reinforces blockchain's fraud-reducing capabilities in audit processes	Yes	No	Yes
Swinkels et al. (2023)	Empirical evidence on the ownership and liquidity of real estate tokens	Regulations towards who owns the tokens	No	Yes	No
Madhwal et al. (2025)	Enhancing Pension Asset Reinvestment via Blockchain Tokenization	Insights to smart contracts, tokenization architectures for regulated asset classes	No	No	Yes
Chen et al. (2024)	Exploring the Security Issues of Real World Assets (RWA)	Discusses explicit fraud risks in tokenized real-world asset systems such as oracle manipulation and double pledging	Yes	Yes	Yes
Tan et al. (2023)	FCToken: A Flexible Framework for Blockchain-Based Compliance Tokenization	Smart contracts, some legal frameworks, system	No	Yes	Yes
Tian et al. (2020)	Finance infrastructure through blockchain-based tokenization	securities law for tokenization	No	Yes	Yes
Crain et al. (2020)	Fixing the fix for silver and gold	Traditional markets, manipulation, infrastructure how these markets work	Yes	No	No
Federal Bureau of Investigation (2011)	Financial Crimes Report to the Public: Fiscal Years 2010–2011	Provides an overview of financial fraud typologies including deception-based schemes. Useful for framing foundational definitions of fraud and contextualizing traditional market risks.	Yes	No	No

Table A.1.1: Systematic Literature Review Summary (Part 1)

Author	Title	Analytical Notes	Fraud Discussed?	Legal Safeguards	Technical Safeguards
Kim et al. (2020)	Fractional ownership, democratization, and bubble formation - The impact of blockchain enabled asset tokenization	Securities law for tokenization, risks and benefits of fractionalization	No	Yes	No
Vitelaru et al. (2023)	Fractional Vehicle Ownership and Revenue Generation Through Blockchain Asset Tokenization	Tokenization combined with automotive industry, how to tokenize vehicle parts	No	No	Yes
Garcia et al. (2015)	Futures market failure?	Relevant for storage issues of underlying assets, critiques systemic inefficiencies and market dynamics in futures markets	Yes	No	No
Lu et al. (2023)	Impacts of CME Changing Mechanism for Allowing Negative Oil Prices on Prices and Trading Activities in the Crude Oil Futures Market	Manipulation relevance for fraud, structural changes in futures markets to allegations of market manipulation	Yes	Yes	No
Marstein et al. (2023)	Implementing Secure Bridges: Learnings from the Secure Asset Transfer Protocol	Interesting protocol for smart contracts to make transfers transparent and secure	No	No	Yes
Rousse et al. (2019)	Informed trading in the WTI oil futures market	Insider trading, insights into insider trading risks relevant to tokenized commodity platforms.	Yes	Yes	No
Gan et al. (2021)	Initial coin offerings, speculation, and asset tokenization	Regulations towards security token offering, explores the speculative nature and market behavior of ICOs	No	Yes	No
Blemus et al. (2020)	Initial crypto-asset offerings (ICOs), tokenization and corporate governance	Relevant by discussing governance weaknesses in ICOs that can enable fraudulent behavior	No	No	Yes
Arnautovic et al. (2025)	Innovating Real Estate Business Models with Blockchain	IoT reference for monitoring and automating, focuses on innovation and efficiency	No	Yes	Yes
Verstein et al. (2016)	Insider trading in commodities markets	Insider trading example	Yes	Yes	No
Lavayssière et al. (2025)	Legal Structures of Tokenised Assets	Very relevant legal, mirroring assets, underlying assets, explores how incomplete tokenization can enable fraud and regulatory evasion in tokenized asset platforms.	No	Yes	No
Heryadi et al. (2021)	Leverage from Blockchain in Commodity Exchange: Asset-Backed Token with Ethereum Blockchain Network and Smart Contract	Proof of collateral, full smart contract architecture for asset-backed tokens	No	No	Yes
Satish et al. (2015)	NSEL's Payment Crisis: Jolt to Indian Commodity Markets	Misrepresentation example for fraud	Yes	Yes	No
Ferrara et al. (2022)	Physical Assets Tokenization for Blockchain Market	Ensuring legitimate token-asset correspondence and outlines risks like third-party fraud and asset misrepresentation.	Yes	No	Yes
Kiskis et al. (2024)	Private law framework for blockchain	Very relevant information related to MiCa, indirectly fraud risk in token legal structures.	No	Yes	Yes
Mistrangelo et al. (2022)	PROPERTY TOKENIZATION DIGITAL FRAMEWORK FOR INCLUSIVE AND SUSTAINABLE ASSET MARKETS DEVELOPMENT	Benefits of tokenizing real estate, mentions adoption is key	No	No	Yes
Mottaghi et al. (2024)	Real Estate Insights: The current state and the new future of tokenization in real estate	Relevant regulators/regulations. MIFID, FINMA, and securities law are discussed. Relevant to fraud discussions	No	Yes	No
Serrano (2022)	Real Estate Tokenisation via Non Fungible Tokens	Mentions manipulation possibility of data in real estate when using blockchain technology	Yes	No	Yes
Henker et al. (2023)	Real Estate Tokenization in Germany: Market Analysis and Concept of a Regulatory and Technical Solution	Securities law, Germany state, different regulations across globally	No	Yes	Yes
Engel (2020)	Regulation, financialization and fraud in Chinese commodity markets after the Global Financial Crisis	Fraud example traditional commodity markets, large-scale warehouse receipt and collateral fraud in Chinese commodity markets	Yes	Yes	No
Dietrich et al. (2022)	Review Of Blockchain-based Tokenization Solutions For Assets In Supply Chains	Transaction history of assets, labeling mechanisms like RFID or QR-codes, relevant by providing a survey of supply chain tokenization systems	No	No	Yes
Oza et al. (2024)	Smart Contracts and Tokenization: Revolutionizing Real Estate Transactions with Blockchain Technology	Fraud with ownership rights, documents etc.	Yes	No	Yes
Beniiche et al. (2022)	Society 5.0: Internet as if People Mattered	Very useful about oracles and smart contracts, blockchain systems which form the infrastructure for preventing or enabling fraud	No	No	Yes
Ilina et al. (2023)	SoK: How Blockchain and Tokenization Will Transform the Energy Sector	Tokenization applications in the energy industry, lack of regulatory clarity	No	Yes	No
Wang and Nixon (2021)	SoK: Tokenization on blockchain	Risks Associated with NFTs	Yes	No	Yes
Garcia-Teruel et al. (2021)	The digital tokenization of property rights. A comparative perspective	Examines legal interoperability in tokenized property systems	No	Yes	Yes
Feuz and Montoya (2021)	The Downfall of Transmar Cocoa	Misrepresentation example for fraud, financial and collateral fraud in a cocoa trading firm	Yes	Yes	No
Pirrong (2017)	The economics of commodity market manipulation: A survey	Provides a comprehensive overview of commodity market manipulation techniques, directly supporting fraud risk analysis in tokenized commodity systems.	Yes	Yes	No
Escobar et al. (2025)	Tokenisation Outcomes Framework for the Public Sector - Is Blockchain Optimal for My Process?	Offers a nice table for tokenisation aspects, identifies trust and transparency outcomes as core benefits of tokenization	No	No	Yes
Joshi and Choudhury (2022)	Tokenization of Real estate Assets Using Blockchain	Information about misrepresentation of assets in asset-backed tokens.	Yes	No	Yes
Gupta et al. (2020)	Tokenization of real estate using blockchain technology	benefits tokenization, securities law, architecture together with smart contracts	No	No	Yes
Baum (2021)	Tokenization - The future of real estate investment?	Regulations, different countries, SEC about securities, practical barriers and risks in tokenizing illiquid real assets	No	Yes	Yes
Tanveer et al. (2025)	Tokenized assets in a decentralized economy: Balancing efficiency, value, and risks	Nice background information, misrepresentation, double selling	Yes	Yes	Yes
Nathan et al. (2023)	Understanding and managing blockchain protocol risks	Different layers and their vulnerabilities	No	No	Yes
European Union (2023)	Markets in Crypto-Assets (MiCA) Regulation	Provides a comprehensive regulatory framework for crypto-assets including asset-referenced tokens, focusing on issuer accountability, investor protection, and platform compliance. Legal relevance.	No	Yes	No
Cascarilla (2019)	Paxos Pax Gold (PAXG): White Paper	A gold token system where each token is backed by gold. Useful for understanding token-asset backing and practical implementation challenges.	Yes	No	Yes

Table A.1.2: Systematic Literature Review Summary (Part 2)