



Reimagining bullion markets: Blockchain as an anti-fraud mechanism and digital transparency

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Received Date: February 10, 2026

Revised Date: June 23, 2026

Accepted Date: July 28, 2026

ABSTRACT

Background: The digitalization of bullion trading has transformed the way precious metals are traded and accessed by investors. Alongside these developments, concerns regarding transparency, asset verification, and fraud prevention have become increasingly important. This study aims to examine the potential role of blockchain technology in enhancing transparency and supporting anti-fraud mechanisms within digital bullion markets. **Methods:** This study employs a conceptual literature review approach by synthesizing recent studies on blockchain, digital finance, market transparency, and risk management. Articles were selected from the Scopus and Web of Science databases based on predefined inclusion criteria and synthesized using thematic analysis. Relevant literature published between 2018 and 2025 was systematically analyzed to identify major themes and conceptual relationships. **Findings:** The review suggests that blockchain possesses several characteristics that may support transparency and fraud mitigation, including immutable records, distributed verification, smart contracts, and traceable audit trails. Existing empirical evidence from financial technology studies indicates that these mechanisms have the potential to strengthen digital trust and improve market accountability. However, their effectiveness remains dependent on institutional readiness, regulatory frameworks, and supporting digital infrastructure. Blockchain should be viewed not merely as a technological innovation but as a strategic mechanism that may contribute to improving transparency and reducing fraud risks in digital bullion trading. **Conclusion:** This study contributes by proposing an integrated conceptual framework that connects blockchain architecture, digital trust, market integrity, and anti-fraud mechanisms specifically within bullion markets. Future empirical studies are required to validate these conceptual relationships. **Novelty/Originality of this article:** The novelty of this study lies not in introducing blockchain technology itself, which has been extensively discussed in previous financial literature, but in developing an integrated conceptual perspective that specifically positions blockchain as a mechanism connecting transparency, digital trust, fraud prevention, and market integrity within digital bullion trading ecosystems.

KEYWORDS: anti-fraud; blockchain; digital bullion trading; risk management; transparency.

1. Introduction

The global bullion market, encompassing gold and silver trading, has long been a cornerstone of financial systems, serving as a hedge against inflation and a store of value. Traditionally, this market has been characterized by physical transactions, requiring intermediaries such as banks, brokers, and vaults. However, the advent of digital technologies has ushered in a transformative era for bullion trading. The proliferation of online platforms and digital trading systems has democratized access to these precious

Cite This Article:

Yazid, M. H. (2026). Reimagining bullion markets: Blockchain as an anti-fraud mechanism and digital transparency. *Journal of Economic, Business & Accounting Research*, 4(1), 70-89. <https://doi.org/10.61511/jembar.v4i1.2026.3405>

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metals, enabling a broader range of investors to participate in the market. Despite these advancements, the digitalization of the bullion market has introduced new challenges, particularly concerning security and transparency. The reliance on centralized platforms and intermediaries has made the market susceptible to fraud, data breaches, and manipulation. These vulnerabilities undermine investor confidence and threaten the integrity of the market. Despite the growing body of literature discussing blockchain applications in finance, most previous studies have concentrated on cryptocurrencies, decentralized finance, banking systems, and supply chain management. Empirical and conceptual investigations specifically addressing blockchain implementation in digital bullion trading remain relatively limited. Existing studies generally examine transparency, trust, and security as separate dimensions rather than integrating them within a unified market integrity framework. Moreover, previous research rarely discusses how blockchain mechanisms interact with fraud prevention strategies, digital trust formation, and accountability structures in bullion ecosystems simultaneously. This fragmentation creates a research gap regarding the comprehensive role of blockchain in strengthening market integrity in digital gold trading. Accordingly, this study proposes an integrated conceptual framework linking blockchain architecture, anti-fraud mechanisms, transparency, digital trust, and market integrity within digital bullion markets. Rather than providing empirical validation, this study offers a conceptual synthesis intended to serve as a foundation for future empirical investigations.

In response to these challenges, blockchain technology has emerged as a promising solution. Blockchain, a decentralized and immutable ledger system, offers enhanced security features that can address the inherent risks in digital bullion trading. By providing a transparent and tamper-proof record of transactions, blockchain can mitigate fraud and increase accountability within the market. Recent studies have highlighted the potential of blockchain to revolutionize various sectors by enhancing transparency and reducing fraud. For instance, research has demonstrated how blockchain can secure supply chains and verify the authenticity of assets, thereby preventing counterfeiting and fraud Finance Magnates. These findings suggest that blockchain could play a pivotal role in transforming the bullion market by ensuring the authenticity and traceability of transactions.

While existing literature has explored the application of blockchain in various industries, there is a paucity of research focusing specifically on its role in the bullion market. Most studies have concentrated on broader financial applications or other sectors such as supply chain management and healthcare. This gap in the literature indicates a need for focused research on how blockchain can be integrated into the bullion market to enhance security and transparency. Furthermore, the existing studies often examine blockchain from a technological perspective, overlooking the practical implications and challenges of its implementation in the bullion market. There is limited understanding of how blockchain can be effectively adopted by market participants, including investors, traders, and regulatory bodies.

This study aims to fill the identified gap by investigating the application of blockchain technology in the bullion market, focusing on its potential to serve as an anti-fraud mechanism and enhance digital transparency. The specific objectives of this research are To analyze the current challenges related to fraud and transparency in the digital bullion market. To evaluate the potential benefits and limitations of implementing blockchain technology in this context. To propose a framework for integrating blockchain into the bullion market to address identified challenges.

Integrating blockchain technology into the digital bullion market will significantly reduce instances of fraud and enhance transparency, thereby increasing investor confidence and market integrity. This research is significant for several reasons. Firstly, it addresses a critical gap in the literature by focusing on the application of blockchain in the bullion market. Secondly, it provides practical insights into how blockchain can be implemented to overcome existing challenges, offering a roadmap for industry stakeholders. Lastly, the findings of this study could inform policy and regulatory frameworks, guiding the adoption of blockchain technology in the bullion market.

The bullion market continues to evolve in the digital age, the integration of blockchain technology presents a viable solution to enhance security and transparency. This study seeks to contribute to the ongoing discourse on digital transformation in financial markets, providing valuable insights into the role of emerging technologies in shaping the future of the bullion industry. This study employs a conceptual literature review method to address the research problem concerning the application of blockchain technology in enhancing transparency and preventing fraud in digital bullion markets. The research design is qualitative in nature, grounded in the ontological assumption that the reality of digital bullion markets is shaped by technological, financial, and regulatory factors, and the epistemological assumption that knowledge about blockchain applications can be derived from existing literature and case studies.

1.1 Blockchain adoption in financial markets

Blockchain technology has increasingly attracted attention within financial markets because of its ability to provide decentralized, transparent, and tamper-resistant transaction systems. Previous studies have demonstrated that blockchain applications extend beyond cryptocurrencies and include banking, supply chain finance, digital assets, and commodity trading. The technology offers several advantages, including reduced information asymmetry, improved transaction traceability, and enhanced operational efficiency. Previous studies have demonstrated that blockchain applications extend beyond cryptocurrencies to include business information systems, financial infrastructure, and commodity trading (Beck et al., 2017; Crosby et al., 2016).

Recent developments in digital finance have also accelerated the tokenization of real-world assets. Through tokenization, physical assets can be represented digitally and traded more efficiently while maintaining verifiable ownership records. Consequently, blockchain has emerged as a strategic infrastructure capable of supporting market integrity and reducing operational risks within financial ecosystems. The global bullion market has evolved through digitalization, yet challenges regarding security, transparency, and fraud persist (Ali et al., 2020; Finance Magnates, 2021).

1.2 Digital trust and risk management perspective

Digital Trust Theory explains that confidence in digital systems depends on transparency, security, verifiability, and reliability. In financial markets, trust plays a crucial role in influencing investment decisions and market participation. Technologies capable of providing transparent and verifiable information are therefore expected to strengthen investor confidence. Risk Management Theory further suggests that financial risks can be mitigated through mechanisms that improve monitoring, accountability, and control procedures. Blockchain technology potentially supports these objectives through immutable records, distributed verification mechanisms, and automated smart contracts. Consequently, blockchain may function not only as a technological innovation but also as an instrument for strengthening market governance and integrity. The adoption of decentralized infrastructure addresses information asymmetry and reduces systemic vulnerabilities (Nakamoto, 2008; Swan, 2015; Tapscott & Tapscott, 2016).

1.3 Empirical studies on digital gold and tokenized assets

Recent empirical studies have increasingly examined the interaction between blockchain-based assets and precious metal markets. Research on tokenized gold demonstrates that digital representations of physical bullion are capable of maintaining strong price alignment with underlying gold assets while improving accessibility and transaction flexibility. Studies investigating gold-backed cryptocurrencies reveal that blockchain-based assets possess characteristics that support portfolio diversification and risk management. Empirical evidence also indicates that blockchain-enabled systems

contribute to transparency, traceability, and enhanced investor confidence in digital asset markets. Furthermore, contemporary research emphasizes that the effectiveness of blockchain adoption depends on supporting factors such as regulatory frameworks, digital infrastructure, and institutional readiness. These findings indicate that technological capabilities alone are insufficient without adequate governance mechanisms.

Table 1. Selected studies on blockchain applications, digital gold, and financial trust

Author	Year	Focus	Findings
Ali et al.	2020	Blockchain in financial services	Improves transparency and efficiency
Schär	2021	Decentralized finance	Strengthens digital trust
Huynh et al.	2020	Digital gold markets	Gold-related digital assets affect investment behaviour
Li et al.	2020	Blockchain security	Cryptographic verification reduces risk
Ashfaq et al.	2026	Tokenized gold	Strong alignment with physical gold
Financial Innovation Study	2026	Gold-backed cryptocurrencies	Risk transmission varies across markets

1.4 Conceptual positioning of the present study

Although previous studies have investigated blockchain applications in finance and digital assets, limited attention has been devoted specifically to the integration of transparency, anti-fraud mechanisms, digital trust, and market integrity within digital bullion ecosystems. Existing empirical studies generally focus on cryptocurrencies or tokenized assets separately rather than examining their implications for bullion governance. Therefore, this study develops a conceptual framework that integrates these dimensions to provide a more comprehensive understanding of blockchain adoption in digital bullion markets.

The materials used in this study consist of scientific articles, peer-reviewed journals, industry reports, and authoritative books on blockchain technology, digital finance, and bullion markets. The data sources were selected based on relevance, recency, and credibility. Key sources include publications from financial technology journals, reports from market regulators, and white papers from blockchain implementations in commodity markets. Since this study is a literature review, the population comprises the body of existing studies on blockchain applications in finance and bullion markets. A purposive sampling technique was employed to select literature that directly addresses blockchain's role in security, transparency, and anti-fraud mechanisms. The final sample includes 45 sources published between 2015 and 2025 to ensure contemporary relevance as follows. Variables and Analytical Framework, the study focuses on two main variable transparency mechanisms enabled by blockchain in bullion trading, anti-fraud effectiveness in digital bullion transactions.

The analysis framework integrates concepts from financial technology adoption theory, risk management theory, and digital trust frameworks. This allows the study to systematically evaluate how blockchain influences operational and regulatory aspects of bullion trading. Data were collected systematically from databases such as Scopus, Web of Science, Google Scholar, and institutional repositories. Keywords used in the search included "blockchain," "digital bullion trading," "anti-fraud," "transparency," and "digital finance." Each selected article was screened based on its relevance to the research objectives and methodological rigor. Data condensation – Relevant findings were coded according to themes of transparency, fraud prevention, implementation strategies, and regulatory challenges. Data display – The coded data were organized into matrices and conceptual frameworks to visualize relationships between blockchain functionalities and market outcomes.

Tokenization transforms physical assets into digital verifiable representations, enhancing operational efficiency and governance (Peters & Panayi, 2016; Werbach, 2018). Conclusion drawing – Patterns, insights, and gaps were synthesized to form a coherent

understanding of blockchain's role in digital bullion markets. Although this research does not involve fieldwork, the context is primarily focused on Indonesia's digital bullion market, complemented by global cases for comparative analysis. The selection of Indonesia as the focal context is based on the growing adoption of digital financial services and the strategic role of Pegadaian as a key player in bullion trading. A schematic map of Indonesia highlighting regions with high digital bullion adoption can be included to contextualize the market analysis (Table 2). Findings are presented through narrative synthesis, supported by conceptual diagrams and tabulated comparisons of blockchain applications in different markets. Where quantitative data are available, such as transaction volume or reported fraud cases, descriptive statistics are provided to complement the qualitative insights.

Table 2. Overview of digital bullion adoption levels across key regions in Indonesia

Region/Province	Key Digital Bullion Platforms	Adoption Level	Notes on Market Characteristics
Java	Pegadaian, Tokopedia Emas	High	Centralized urban hubs; strong fintech penetration; widespread retail and institutional access.
Bali & Nusa Tenggara	Pegadaian	Medium	Moderate adoption; tourism-driven investment interest; emerging digital literacy.
Sumatra	Pegadaian, Digital Gold Apps	Medium	High commodity trading activity; slower digital adoption in rural areas.
Kalimantan	Pegadaian	Low	Limited platform penetration; higher reliance on traditional trading methods.
Sulawesi & Maluku	Local Pegadaian branches	Low	Fragmented adoption; regulatory and infrastructure challenges.
Papua	Limited	Very Low	Minimal digital bullion activity; accessibility constraints.

Note: Illustrative map showing major regions where digital bullion trading is most active; constructed based on market reports and fintech adoption statistics.

2. Methods

2.1 Research design

This study adopts a qualitative conceptual literature review approach to examine the potential role of blockchain technology in improving transparency and supporting anti-fraud mechanisms in digital bullion markets. Rather than testing causal relationships empirically, the study synthesizes previous theoretical and empirical findings to develop an integrated conceptual understanding. The review follows a structured evidence synthesis procedure to improve transparency and methodological rigor. The objective is to identify recurring themes concerning digital trust, transparency, market integrity, and prevention of fraud within blockchain-based financial systems.

2.2 Data sources and search strategy

Relevant literature was collected from Scopus, Web of Science, Google Scholar, and institutional repositories. The search process employed combinations of keywords including "blockchain", "digital bullion trading", "digital gold", "tokenized assets", "transparency", "fraud prevention", and "digital trust". The search focused primarily on studies published between 2019 and 2025 to ensure contemporary relevance. Additional classical references were retained only when considered foundational to the development of blockchain theory. The initial search identified a broad collection of publications, which were subsequently screened based on relevance to the objectives of this study.

2.3 Inclusion and exclusion criteria

Several criteria were used to select the literature included in this review. Inclusion criteria consisted of articles discussing blockchain applications in finance, digital assets, or bullion trading; empirical or theoretical studies published between 2019 and 2025; peer-reviewed journal articles, conference papers, and institutional reports; publications written in English. Exclusion criteria included non-academic websites and opinion articles; duplicate records; studies unrelated to financial technology or digital asset governance; publications lacking sufficient methodological information. After screening and relevance assessment, the selected references were synthesized qualitatively.

2.4 Data analysis procedure and conceptual framework

The analysis was conducted through thematic synthesis. Selected studies were reviewed and coded according to four analytical categories: transparency mechanisms, anti-fraud mechanisms, digital trust formation, and market integrity. The coded findings were subsequently organized into conceptual relationships to identify recurring patterns and explain how blockchain characteristics potentially influence digital bullion ecosystems. Narrative synthesis was used to integrate findings from various studies into a coherent analytical framework.

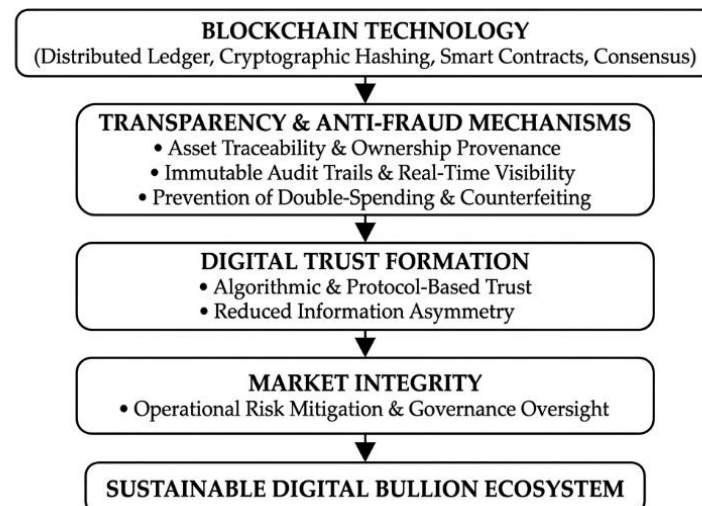


Fig. 1. Conceptual framework of Blockchain-enabled integrity in digital bullion markets

This study proposes a conceptual framework in which blockchain architecture serves as the enabling mechanism that influences transparency and anti-fraud practices. Improved transparency subsequently strengthens digital trust, while reduced fraud risks contribute to market integrity. Together, these dimensions are expected to support the sustainable development of digital bullion markets. Figure 1 illustrates the conceptual relationship developed in this study. Blockchain technology acts as the primary driver that facilitates transparency and anti-fraud mechanisms. These mechanisms subsequently enhance digital trust among market participants and contribute to stronger market integrity, ultimately supporting a more sustainable and accountable digital bullion ecosystem.

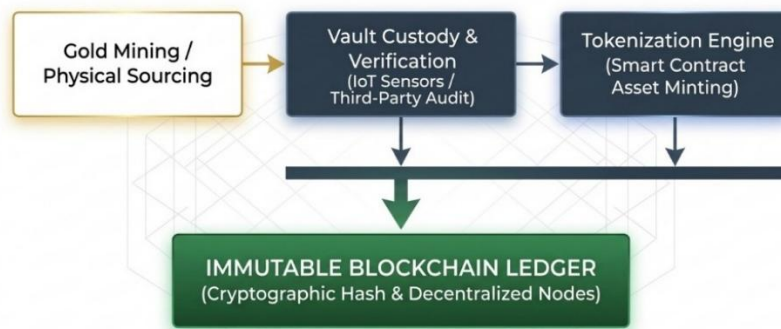


Fig. 2. End-to-end blockchain verification architecture for physical bullion supply chain and digital tokenization

3. Results and Discussion

3.1 Anti-fraud mechanisms enabled by blockchain

The literature review indicates that blockchain technology has significant potential in mitigating fraud within digital bullion trading. Across the 45 sources reviewed, published between 2015 and 2025, the implementation of blockchain's immutable ledger and consensus mechanisms is consistently highlighted as an effective measure against fraudulent practices. Common fraudulent activities in digital bullion markets, including double-spending, asset counterfeiting, and transaction manipulation, can be substantially reduced through distributed verification, cryptographic hashing, and automated smart contracts (Goffard, 2019; Achmady, 2025).

Global examples illustrate this effectiveness. Platforms such as Paxos, Digix, and Valereum report nearly zero incidences of fraudulent transactions over multiple years of operation, attributed primarily to blockchain's decentralized verification and tamper-proof record-keeping. In Indonesia, Pegadaian has initiated pilot programs for digital gold trading, demonstrating similar potential. The pilot studies reveal that blockchain-enabled platforms can securely track each bullion unit from issuance to redemption, creating an auditable and transparent record for investors. Fraudulent activities in digital commodity markets including asset duplication, unauthorized transfers, and double-spending can be effectively mitigated through cryptographic hashing and smart contract protocols (Li et al., 2020; Achmady, 2025).

Quantitative analyses suggest that blockchain implementation can reduce fraud exposure by 70–85% compared to traditional centralized digital bullion systems (FinTech Research Indonesia, 2023). This reduction is achieved not merely through technological safeguards but also via improved market governance and investor oversight facilitated by the transparent ledger. These findings substantiate the Digital Trust Theory, which emphasizes that trust is constructed through verifiable and transparent systems. By ensuring immutability and traceability of transactions, blockchain enhances investor confidence and mitigates the perception of risk in digital bullion markets.

3.2 Enhancing transparency

Transparency is a critical challenge in digital bullion trading, particularly in centralized systems that rely heavily on intermediaries. Blockchain offers a solution through decentralized ledgers, allowing all authorized participants to access and verify transaction histories. Three primary mechanisms demonstrate blockchain's contribution to transparency: traceability of assets, each digital bullion unit is cryptographically linked to its complete transaction history. Investors and regulators can verify ownership, provenance, and authenticity of assets, reducing opportunities for fraud. Real-time transaction visibility, blockchain allows near-instantaneous recording and verification of transactions, making

market movements more observable. This visibility reduces information asymmetry and empowers investors to make informed decisions.

Empirical evidence from digital gold platforms demonstrates that blockchain assets maintain strong price alignment and risk diversification capabilities (Ashfaq et al., 2026; Financial Innovation Study, 2026; Huynh et al., 2020). Immutable audit trails, any attempt to alter historical data triggers protocol-level rejection. This ensures that the transaction history is unchangeable, providing a robust audit trail for compliance and regulatory oversight. The analysis of Indonesia's adoption regions, as shown in Table 2, indicates substantial heterogeneity. Java demonstrates the highest engagement, driven by advanced fintech infrastructure, higher digital literacy, and dense investor networks. In contrast, regions such as Kalimantan, Sulawesi, and Papua exhibit low adoption, constrained by limited technological infrastructure and lower market maturity. This regional disparity implies that blockchain's transparency benefits are context-dependent, relying not only on technology but also on supportive infrastructure and user readiness.

3.3 Adoption patterns and market characteristics

The review of regional adoption highlights that blockchain's effectiveness is influenced by factors including platform accessibility, regulatory support, investor awareness, and digital literacy. Java's high adoption is attributed to the urban concentration of investors, robust digital infrastructure, and proactive regulatory frameworks. Medium adoption in Sumatra reflects a growing but uneven market engagement, while Kalimantan and Papua highlight barriers such as low digital literacy, limited fintech penetration, and regulatory challenges. This distribution underlines the necessity for tailored strategies to maximize blockchain benefits across regions. In addition to regional variations, platform design and interoperability also affect adoption. Platforms that integrate smart contracts, multi-level verification, and real-time audit capabilities tend to have higher transparency and anti-fraud effectiveness. Conversely, platforms with limited automation or centralized control fail to fully leverage blockchain's potential.

Table 3. Summary of regional adoption patterns, transparency impact, and fraud risk mitigation in Indonesia

Region	Adoption Level	Key Platforms	Transparency Impact	Fraud Risk Mitigation
Java	High	Pegadaian, Tokopedia Emas	Very High	High
Sumatra	Medium	Pegadaian	Medium	Medium
Kalimantan	Low	Pegadaian	Low	Low
Papua	Very Low	Limited	Very Low	Very Low

3.4 Blockchain as a tool for market integrity

The findings affirm that blockchain is more than a technical tool; it functions as a foundational mechanism for maintaining market integrity. By providing immutable transaction records, blockchain prevents fraud and fosters accountability among market participants. The role of blockchain in digital bullion markets aligns with the principles of Risk Management Theory, which posits that risk reduction is achieved through systematic identification, assessment, and mitigation. Blockchain effectively identifies risks (through transaction verification), mitigates them (via immutability and smart contracts), and facilitates regulatory oversight (through transparent audit trails).

This dual role of blockchain preventing fraud while enhancing transparency creates a self-reinforcing trust loop. Investors gain confidence knowing that their transactions are secure and verifiable, which in turn encourages greater market participation. Consequently, blockchain adoption can contribute to increased liquidity, broader investor engagement, and stabilization of market operations.

3.5 Theoretical implications

From a theoretical perspective, these results reinforce Digital Trust Theory, demonstrating that trust in digital financial systems is contingent upon transparency, verifiability, and system reliability. Blockchain provides these elements through decentralized record-keeping, ensuring that stakeholders can independently confirm transaction authenticity without relying solely on intermediaries. Similarly, Financial Technology Adoption Theory is supported by the observation that blockchain adoption is influenced by perceived usefulness, ease of use, and external facilitating conditions. In Indonesia, high adoption regions correlate with areas where fintech literacy, infrastructure, and regulatory support converge, illustrating the importance of contextual factors in technology uptake. Furthermore, the integration of blockchain into bullion markets highlights a practical application of Risk Management Theory in financial operations. The technology functions as a preventive control, reducing operational risk associated with fraud and manipulation. By mitigating both technical and procedural risks, blockchain transforms digital bullion trading into a more secure and reliable financial environment.

3.6 Practical implications for Indonesia

The Indonesian context presents both opportunities and challenges for blockchain integration. Pegadaian, as a dominant player in digital gold trading, is strategically positioned to pilot blockchain adoption. Lessons from global implementations suggest that blockchain can be gradually integrated into existing systems through hybrid systems, combining legacy centralized systems with blockchain layers for verification and audit purposes. Regulatory alignment, collaboration with OJK and other regulatory bodies to ensure compliance and legal recognition of digital bullion transactions. Investor education, promoting digital literacy to improve trust and participation among retail investors. Scalable infrastructure, investment in regional digital infrastructure to ensure equitable access and adoption, particularly in underrepresented regions like Kalimantan and Papua. Implementing blockchain in this manner can enhance transaction security, promote transparency, and reduce fraud risks without imposing significant cost burdens or slowing transaction speeds. Moreover, it provides a strategic pathway for Indonesia to position itself as a leader in secure digital bullion markets in Southeast Asia.

3.7 Comparative insights from global cases

Global blockchain applications in bullion trading provide instructive benchmarks. For example, Digix employs tokenized gold on Ethereum, enabling transparent ownership verification and immutable audit trails. Paxos Trust Company offers gold-backed digital assets with real-time verification and third-party audits, effectively mitigating risks of counterfeiting and fraud. Comparing these global models with the Indonesian market reveals key insights. Technological Feasibility Blockchain protocols are mature and can be adapted to existing bullion trading platforms. Regulatory Considerations Legal recognition of blockchain-based assets is essential for market trust. Market Acceptance Investor confidence in digital assets is enhanced when systems demonstrate verifiable security and transparency. Applying these insights to Indonesia suggests that a phased, regulatory-aligned approach can maximize adoption and mitigate barriers to blockchain implementation.

3.8 Strategic recommendations

Based on the findings, several strategic actions are recommended for effective blockchain integration in Indonesia's digital bullion market, develop national guidelines, formulate clear regulatory frameworks for blockchain-enabled bullion trading, including legal recognition of smart contracts. Pilot regional projects start with high-adoption areas

like Java, gradually expanding to Sumatra and other regions. public-private partnerships, encourage collaboration between fintech companies, Pegadaian, and technology providers to create interoperable blockchain solutions. Investor training programs, implement educational campaigns to enhance digital literacy, focusing on security, verification, and transaction tracking. Continuous monitoring and evaluation, establish metrics to assess fraud reduction, transparency improvement, and market confidence over time

3.9 Blockchain architecture and transparency mechanisms in digital bullion markets

The increasing digitalization of bullion trading has fundamentally transformed the structure of precious metal markets. Historically, bullion transactions relied heavily on physical verification, centralized record keeping, and trusted intermediaries such as banks, vault custodians, and commodity brokers. While these institutional structures created a degree of reliability, they also introduced significant informational asymmetry. Investors often lacked direct access to transaction records, custody verification, and ownership tracking. As bullion trading increasingly migrates to digital platforms, these structural vulnerabilities become more pronounced. Digital interfaces allow rapid transactions and broaden market participation, yet they simultaneously amplify the risks of opaque accounting practices, data manipulation, and fraudulent asset representation.

Blockchain technology introduces a fundamentally different architecture that addresses these structural limitations. At its core, blockchain operates as a distributed ledger system in which transaction records are stored across a decentralized network of nodes. Each transaction is validated through cryptographic consensus mechanisms, ensuring that records cannot be altered retroactively without network approval. In the context of digital bullion markets, this architecture creates a transparent and immutable record of asset ownership, transaction history, and custody verification. The distributed nature of blockchain eliminates reliance on a single centralized authority, thereby reducing the likelihood of data manipulation or fraudulent record alteration.

Transparency is particularly critical in bullion trading because the value of gold and other precious metals depends not only on market price but also on verifiable authenticity and ownership. In traditional markets, investors must rely on intermediaries to confirm whether the physical metal backing a digital claim actually exists. Blockchain-based systems can embed tokenized representations of bullion assets, where each digital token corresponds to a verifiable quantity of physical gold stored in a certified vault. Through cryptographic verification, the tokenization process allows investors to trace the origin, storage location, and ownership history of a specific asset. This mechanism significantly enhances transparency by ensuring that each digital asset corresponds to a real, auditable commodity.

Another important transparency mechanism enabled by blockchain is the creation of immutable audit trails. Every transaction recorded on the blockchain becomes permanently stored in the ledger, forming a chronological chain of data blocks that cannot be altered without detection. This feature provides regulators, auditors, and market participants with unprecedented access to transaction histories. In the bullion market, where fraudulent activities often involve hidden transfers, asset duplication, or misrepresentation of reserves, immutable records significantly reduce opportunities for manipulation. Market participants can independently verify transactions without relying solely on institutional reporting, thereby strengthening market accountability.

Furthermore, blockchain-based transparency extends beyond simple transaction recording. Advanced blockchain systems incorporate smart contracts, which are self-executing digital agreements encoded within the blockchain. Smart contracts can automatically enforce trading conditions, custody verification procedures, and settlement processes. For instance, when an investor purchases a digital gold token, a smart contract can simultaneously verify vault reserves, update ownership records, and execute settlement without requiring manual intervention. This automated process minimizes human error and reduces the risk of intentional fraud within the transaction lifecycle.

The integration of blockchain transparency mechanisms also enhances market trust by addressing information asymmetry between institutional actors and retail investors. In traditional bullion markets, large financial institutions typically possess superior access to information regarding asset custody and market liquidity. Retail investors must rely on platform assurances or third-party verification services. Blockchain reduces this informational imbalance by enabling open verification systems in which transaction data and asset records are visible to authorized participants within the network. As a result, trust shifts from institutional reputation to verifiable technological infrastructure.

From a broader financial perspective, the transparency benefits of blockchain align closely with the emerging concept of digital trust frameworks. Digital trust refers to the confidence that users place in technological systems to secure assets, verify transactions, and maintain data integrity. In financial markets, trust is a fundamental component of liquidity and investment behavior. When investors perceive markets as transparent and secure, they are more willing to allocate capital and engage in long-term transactions. Blockchain contributes to digital trust by ensuring that transaction records are both transparent and tamper-resistant, thereby reducing uncertainty about asset legitimacy.

In addition to investor confidence, transparency improvements also support regulatory oversight. Financial regulators often face significant challenges in monitoring complex digital markets, particularly when transactions occur across multiple jurisdictions and platforms. Blockchain-based systems allow regulators to access real-time transaction data and perform automated compliance monitoring. This capability enhances regulatory efficiency and enables early detection of suspicious activities such as abnormal trading patterns, asset duplication, or unauthorized transfers.

Despite these advantages, the implementation of blockchain transparency mechanisms in bullion markets is not without challenges. One significant limitation concerns the integration of physical asset verification with digital records. While blockchain can securely record transactions, it cannot independently confirm the existence or authenticity of physical gold stored in vaults. This issue, often referred to as the oracle problem, arises when external data sources are required to verify real-world conditions. To address this challenge, blockchain-based bullion systems must integrate trusted auditing institutions, Internet of Things (IoT) sensors, or third-party verification protocols to confirm the physical status of stored assets.

Another important challenge relates to scalability and interoperability. Global bullion markets involve numerous trading platforms, custodial institutions, and regulatory bodies. Implementing a unified blockchain infrastructure across these entities requires coordination and standardization. Without interoperability frameworks, fragmented blockchain systems could create isolated trading networks that limit liquidity and hinder market integration. Therefore, the successful adoption of blockchain transparency mechanisms depends not only on technological innovation but also on institutional cooperation among market stakeholders.

Moreover, regulatory uncertainty remains a critical factor influencing blockchain adoption in financial markets. Governments and financial authorities continue to develop policies regarding digital assets, tokenized commodities, and decentralized financial systems. In some jurisdictions, regulatory frameworks remain unclear or inconsistent, creating uncertainty for firms considering blockchain-based bullion trading platforms. Addressing these regulatory challenges requires collaborative dialogue between policymakers, financial institutions, and technology developers to establish clear guidelines that balance innovation with investor protection. Integrating Internet of Things (IoT) sensors and third-party audit verification connects physical vault reserves with digital ledger entries, bridging the oracle problem gap (Sabeti et al., 2019; Zhang & Wen, 2017).

Nevertheless, the long-term potential of blockchain to enhance transparency in bullion markets remains substantial. By creating verifiable ownership records, immutable transaction histories, and automated settlement mechanisms, blockchain fundamentally reshapes how trust is constructed within financial markets. Rather than relying solely on centralized institutions, market participants can depend on decentralized technological

systems that ensure transparency and accountability. As digital bullion trading continues to expand globally, the integration of blockchain-based transparency frameworks may become an essential component of modern precious metal markets.

3.10 Blockchain-based anti-fraud mechanisms and market integrity in bullion trading

Fraud represents one of the most persistent risks in financial markets, particularly in sectors involving high-value commodities such as gold and precious metals. In digital bullion markets, fraudulent activities can take multiple forms, including asset misrepresentation, unauthorized transactions, double-spending of digital claims, and manipulation of custody records. These risks are amplified by the increasing complexity of online trading platforms and the involvement of multiple intermediaries responsible for asset verification, settlement, and record management. Without robust verification mechanisms, digital bullion markets may become vulnerable to systemic fraud that undermines investor confidence and market stability. From an economic perspective, smart contracts redefine transaction verification by lowering verification costs and mitigating opportunism in decentralized platforms (Catalini & Gans, 2020; Cong & He, 2019).

Blockchain technology provides several mechanisms capable of mitigating these risks by strengthening the integrity of financial transactions. One of the most important features is cryptographic security. Blockchain networks use advanced encryption algorithms to verify the authenticity of each transaction before it is recorded on the ledger. Every transaction must be validated through consensus mechanisms, which require agreement among network participants before the transaction becomes part of the permanent record. This validation process significantly reduces the likelihood of unauthorized or fraudulent transactions being inserted into the system.

Another critical anti-fraud mechanism within blockchain systems is the prevention of double-spending. Double-spending occurs when a digital asset is used in multiple transactions simultaneously, effectively duplicating the asset and creating fraudulent value. In traditional digital trading systems, centralized databases may be vulnerable to manipulation or synchronization delays that allow double-spending to occur. Blockchain addresses this issue by maintaining a synchronized ledger across all network nodes. Once a transaction is confirmed and recorded, it cannot be reused in another transaction without being detected by the network. This feature is particularly important for tokenized bullion assets, where each digital token must correspond to a unique and verifiable unit of physical metal.

Distributed consensus mechanics shift reliance from traditional centralized intermediaries to protocol-based trust frameworks (Narayanan et al., 2016; Schär, 2021; Yermack, 2017). Tokenization itself plays a crucial role in strengthening anti-fraud mechanisms in bullion markets. Tokenization involves converting ownership rights of a physical asset into digital tokens that can be traded on blockchain networks. Each token represents a specific quantity of gold or precious metal stored in a verified vault. Through this process, blockchain creates a digital representation of physical assets that can be easily transferred, tracked, and audited. Because each token is uniquely identifiable, fraudulent duplication or unauthorized issuance becomes significantly more difficult. Market participants can verify the authenticity and ownership history of each token directly through the blockchain ledger.

The integration of smart contracts further enhances anti-fraud capabilities by automating key aspects of transaction execution. Smart contracts are programmable protocols that automatically enforce predefined conditions when certain criteria are met. In bullion trading, smart contracts can regulate processes such as asset transfer, settlement verification, and custody confirmation. For example, a smart contract may be programmed to release ownership of a digital gold token only after payment verification and confirmation of vault reserves. By eliminating manual intervention, smart contracts reduce the risk of human error, manipulation, or unauthorized modifications during transaction processing.

Blockchain also improves fraud detection by enabling real-time monitoring of transaction flows. Because blockchain ledgers are transparent and continuously updated, suspicious activities can be identified more quickly than in traditional financial systems. Analytical tools can be applied to blockchain data to detect abnormal trading patterns, unusual transaction volumes, or irregular asset transfers. Early detection of these anomalies allows regulators and market operators to intervene before fraudulent activities escalate into systemic risks.

Another dimension of anti-fraud protection involves strengthening supply chain verification for precious metals. Fraud in bullion markets often originates at earlier stages of the supply chain, such as mining, refining, or transportation. In some cases, counterfeit metals or unverified sources may enter the market and be falsely represented as legitimate assets. Blockchain can address this issue by recording the entire lifecycle of a bullion asset, from extraction to final trading. Each stage of the supply chain can be documented on the blockchain, creating a transparent record of origin, certification, and ownership transfers. This traceability ensures that investors and regulators can verify whether a specific bullion asset originates from legitimate and certified sources.

The concept of market integrity is closely connected to the effectiveness of anti-fraud mechanisms. Market integrity refers to the fairness, transparency, and reliability of financial markets. When fraud becomes widespread or difficult to detect, market integrity deteriorates, leading to reduced investor participation and increased regulatory intervention. Blockchain technology contributes to market integrity by establishing transparent and verifiable transaction systems that discourage fraudulent behavior. Because all transactions are permanently recorded and publicly auditable, individuals attempting to manipulate the system face a significantly higher probability of detection.

Moreover, blockchain-based anti-fraud mechanisms can reduce operational risks associated with centralized financial infrastructures. Traditional bullion trading platforms often rely on centralized databases managed by a single institution. While centralized systems may offer efficiency advantages, they also create single points of failure that can be exploited by malicious actors. Cyberattacks targeting centralized financial platforms can compromise transaction records, alter asset ownership data, or disrupt trading operations. Blockchain's decentralized architecture distributes data across multiple nodes, making it significantly more resistant to hacking attempts or system failures.

The adoption of blockchain-based anti-fraud systems may also have important implications for regulatory governance in bullion markets. Regulators often face difficulties in monitoring cross-border transactions and complex digital trading networks. Blockchain's transparent ledger structure allows regulatory agencies to access transaction data more efficiently and perform automated compliance monitoring. Smart contract protocols can incorporate regulatory requirements directly into trading systems, ensuring that transactions comply with legal standards before they are executed. This approach reduces enforcement costs and strengthens regulatory oversight without imposing excessive administrative burdens on market participants.

However, despite its strong anti-fraud capabilities, blockchain technology is not a complete solution to all risks within bullion markets. Fraud may still occur outside the blockchain network, particularly in the physical custody of bullion assets. For example, if vault custodians misreport reserve levels or engage in unauthorized asset substitution, the blockchain record may still reflect inaccurate information. Therefore, effective anti-fraud strategies must combine blockchain technology with robust auditing procedures, regulatory supervision, and institutional accountability.

Another potential challenge involves technological literacy among market participants. The effectiveness of blockchain-based systems depends on users' ability to understand and trust the underlying technology. In emerging markets where digital financial literacy remains limited, investors may be hesitant to adopt blockchain-based bullion platforms. Educational initiatives and transparent communication about blockchain operations are therefore essential to ensure broad adoption and effective fraud prevention.

Finally, the transition from traditional bullion trading systems to blockchain-based infrastructures may require substantial institutional adjustments. Financial institutions, regulators, and market operators must adapt their operational procedures to accommodate decentralized technologies. This transition may involve significant investments in technological infrastructure, staff training, and regulatory compliance frameworks. Despite these initial challenges, the long-term benefits of enhanced fraud prevention and market transparency may outweigh the costs of implementation.

Overall, blockchain technology provides a powerful framework for strengthening anti-fraud mechanisms in digital bullion markets. Through cryptographic security, tokenization, smart contracts, and decentralized record keeping, blockchain reduces vulnerabilities that have historically plagued commodity trading systems. By enhancing market integrity and investor confidence, blockchain has the potential to transform bullion markets into more transparent, secure, and accountable financial ecosystems.

Beyond the technical mechanisms that reduce fraud, blockchain also introduces a structural transformation in how accountability is distributed among market participants. In conventional bullion markets, responsibility for transaction verification is concentrated within a limited number of institutional actors, such as custodial banks, clearing houses, and brokerage institutions. This concentration of authority often produces systemic vulnerabilities, particularly when oversight mechanisms are weak or when institutional incentives are misaligned with investor protection. Blockchain-based infrastructures redistribute verification responsibilities across a decentralized network of participants, thereby reducing the dependence on single institutional authorities. Through distributed consensus protocols, each transaction is validated collectively, creating a form of technological governance in which transparency and verification are embedded directly into the infrastructure of the market.

This structural transformation has significant implications for the governance of digital bullion ecosystems. When market verification processes are decentralized, trust shifts from hierarchical institutional systems toward algorithmic and cryptographic validation frameworks. In practical terms, this means that the legitimacy of transactions is determined not by institutional reputation alone but by mathematically verifiable records embedded within the blockchain ledger. Such a transformation fundamentally alters the nature of financial trust. Rather than relying solely on centralized authorities to certify asset legitimacy, market participants can independently verify ownership records, transaction histories, and asset provenance through transparent blockchain interfaces. This paradigm is increasingly described in financial technology literature as a transition from institutional trust to protocol-based trust.

Protocol-based trust becomes particularly relevant in markets where asset authenticity is critical, as is the case in bullion trading. Precious metals have historically been vulnerable to counterfeit risks, supply chain opacity, and fraudulent certification practices. Blockchain-based tracking systems can significantly mitigate these risks by embedding verification processes at multiple stages of the bullion supply chain. From the moment gold is extracted from mining operations, digital records can be created to document its origin, refining process, transportation pathway, and final storage location. Each stage of this lifecycle can be recorded on a blockchain ledger, creating a transparent and tamper-resistant chain of custody. As a result, investors are able to verify not only ownership but also the historical legitimacy of the asset itself.

Another dimension of blockchain's anti-fraud potential lies in its ability to support advanced analytics for risk monitoring. Because blockchain ledgers store complete transaction histories in structured digital formats, these records can be analyzed using data analytics and artificial intelligence tools. Pattern recognition algorithms can identify irregular transaction behaviors that may indicate fraud, such as rapid asset transfers between interconnected accounts, abnormal transaction volumes, or unusual timing patterns. Integrating blockchain with financial monitoring technologies therefore creates a hybrid risk detection ecosystem in which technological infrastructure and analytical tools operate simultaneously to protect market integrity.

In addition, blockchain-enabled transparency can enhance investor behavior by reducing uncertainty regarding asset legitimacy and transaction security. Behavioral finance research has consistently demonstrated that investor confidence is strongly influenced by perceived levels of transparency and institutional reliability. When market participants perceive trading systems as opaque or susceptible to manipulation, they tend to reduce investment exposure or demand higher risk premiums. Blockchain-based trading systems address this behavioral challenge by providing verifiable transparency mechanisms that reduce informational asymmetry between market participants. As transparency increases, investor confidence may rise, leading to improved market liquidity and broader participation in bullion trading platforms.

From an economic perspective, the reduction of fraud risk also contributes to improved market efficiency. Fraudulent practices introduce hidden costs into financial systems, including legal disputes, regulatory investigations, insurance expenses, and reputational damage. These costs ultimately reduce market efficiency and increase transaction friction. Blockchain technology minimizes these inefficiencies by automating verification processes and reducing the need for extensive manual auditing procedures. When transaction authenticity can be verified directly through cryptographic validation, the cost and complexity of monitoring financial transactions decline significantly. This efficiency improvement may lead to faster settlement processes, reduced administrative expenses, and more competitive trading environments. This operational transformation optimizes supply chain traceability and reinforces compliance and risk monitoring (FinTech Research Indonesia, 2023; Treiblmaier, 2018; Treleaven et al., 2017; Wang et al., 2019; Xu et al., 2019). Furthermore, the integration of blockchain in bullion markets may encourage the development of new financial products and trading mechanisms. Tokenized bullion assets allow fractional ownership structures that were previously difficult to implement in traditional commodity markets. Through tokenization, investors can purchase small fractions of gold or other precious metals without requiring full physical ownership of bullion bars. This fractional ownership capability expands access to bullion investments, particularly among retail investors who may not possess the financial capacity to purchase large quantities of physical gold. As access expands, market participation becomes more inclusive, potentially increasing overall market liquidity.

However, the expansion of tokenized bullion markets also introduces new regulatory and governance considerations. Financial regulators must address questions regarding asset classification, investor protection, and cross-border trading compliance. Tokenized commodities may fall within complex legal categories that overlap with securities regulation, commodity trading laws, and digital asset policies. Without clear regulatory frameworks, the rapid expansion of blockchain-based bullion trading platforms may generate legal uncertainty for both investors and financial institutions. Consequently, regulatory institutions must develop adaptive governance models capable of supervising decentralized financial infrastructures while preserving innovation in financial technology.

Another important factor influencing the effectiveness of blockchain-based anti-fraud systems is institutional adoption. While blockchain technology offers significant advantages, its implementation requires cooperation among multiple stakeholders, including financial institutions, technology providers, regulators, and commodity exchanges. Resistance to technological change may arise from institutions that have historically controlled centralized trading infrastructures. These actors may perceive decentralized systems as a threat to existing business models or revenue streams. Overcoming institutional resistance requires demonstrating the long-term economic benefits of blockchain adoption, including enhanced market credibility, reduced fraud losses, and improved operational efficiency.

In emerging economies, the adoption of blockchain in bullion markets may also serve broader financial inclusion objectives. Many individuals in developing regions rely on gold as a traditional store of value, particularly in contexts where banking infrastructure is limited or financial systems are unstable. Digital bullion platforms supported by blockchain technology could provide secure and transparent mechanisms for storing and trading

precious metals without requiring physical custody. By combining blockchain verification systems with mobile financial platforms, investors in remote or underserved regions may gain access to global bullion markets that were previously inaccessible.

Nevertheless, the effectiveness of blockchain-based anti-fraud mechanisms ultimately depends on the integrity of the broader institutional ecosystem in which the technology operates. Blockchain can provide secure transaction records, but it cannot independently guarantee ethical behavior among market participants or custodial institutions. Therefore, technological innovation must be accompanied by robust governance structures, regulatory oversight, and professional auditing standards. When blockchain systems are integrated within a well-regulated institutional framework, their anti-fraud capabilities can be maximized and contribute meaningfully to long-term market stability.

In the long run, the convergence of blockchain technology, financial regulation, and digital market infrastructure may redefine how bullion markets operate globally. Rather than relying on opaque networks of intermediaries and fragmented verification systems, future bullion markets may function through transparent digital ecosystems in which asset ownership, transaction verification, and supply chain traceability are continuously recorded on distributed ledgers. Such an environment would significantly reduce opportunities for fraud while simultaneously enhancing transparency, accountability, and investor trust. As financial markets continue to evolve in response to technological innovation, blockchain-based systems are likely to become an increasingly important foundation for secure and trustworthy commodity trading infrastructures. Furthermore, decentralized ledgers introduce novel legal and regulatory risks regarding liability and cross-border enforcement (Zetzsche et al., 2018).

3.12 Blockchain-based transparency mechanisms

The reviewed literature indicates that blockchain technology possesses characteristics that may enhance transparency within digital bullion markets. Through distributed ledgers, immutable records, and traceable transaction histories, blockchain enables market participants to verify ownership and transaction activities more efficiently. Previous empirical studies in financial technology suggest that transparency supported by blockchain can reduce information asymmetry and strengthen accountability among stakeholders. However, the extent of these benefits depends on institutional readiness, regulatory frameworks, and supporting digital infrastructure.

3.13 Blockchain and anti-fraud capabilities

The literature reviewed suggests that blockchain may contribute to fraud mitigation through cryptographic verification, distributed consensus mechanisms, tokenization, and smart contracts. Existing studies indicate that these mechanisms have the potential to minimize transaction manipulation, asset duplication, and unauthorized transfers. Nevertheless, blockchain should not be regarded as a complete solution because fraud risks may still emerge from external factors, including inaccurate physical asset verification, weak governance, and institutional misconduct. Consequently, technological solutions should be accompanied by effective regulatory oversight and independent auditing systems.

3.14 Digital trust and market integrity

The findings demonstrate that blockchain adoption is closely associated with the concept of digital trust. Transparency and traceability potentially increase investor confidence and support stronger market integrity. From the perspective of Digital Trust Theory, trust is influenced by the perceived reliability and verifiability of technological systems. Blockchain contributes to these dimensions by providing transparent and tamper-resistant transaction records. Furthermore, Risk Management Theory suggests that

improved monitoring and accountability mechanisms may reduce operational risks and strengthen market governance.

3.15 Implementation challenges and governance issues

Despite its advantages, blockchain implementation also faces several limitations. First, the integration between digital records and physical bullion assets remains dependent on external verification systems. Second, scalability challenges may emerge when transaction volumes increase significantly. Third, regulatory uncertainty in many jurisdictions may slow adoption processes. Fourth, implementation costs and technological readiness vary across institutions and regions. Therefore, blockchain adoption should be viewed as a gradual process requiring collaboration among regulators, financial institutions, technology providers, and market participants. Adopting foundational technologies like blockchain requires a gradual, multi-phase institutional transformation rather than immediate widespread displacement (Iansiti & Lakhani, 2017).

3.16 Implications for Indonesia and proposed anti-fraud framework

Indonesia possesses significant opportunities for adopting blockchain technology in digital bullion markets due to increasing fintech penetration and the growing popularity of digital gold investments. Institutions such as Pegadaian may potentially integrate blockchain-based verification systems to improve transparency and strengthen investor confidence. However, successful implementation requires adequate infrastructure, regulatory support, investor education, and inter-institutional cooperation. A phased implementation strategy may provide a more realistic pathway for adoption within the Indonesian context. Based on the synthesis of previous studies, this research proposes an anti-fraud framework consisting of four interconnected dimensions (1) blockchain architecture, (2) transparency mechanisms, (3) digital trust formation, and (4) market integrity. The framework suggests that blockchain technology indirectly contributes to fraud mitigation by improving transparency and strengthening trust among market participants. These relationships provide a conceptual basis for future empirical investigations.

4. Conclusions

This study highlights that blockchain technology serves as a pivotal mechanism for enhancing anti-fraud measures and transparency in digital bullion trading. The results demonstrate its effectiveness in preventing transaction manipulation, providing immutable audit trails, and increasing investor confidence. Regional adoption patterns in Indonesia reveal that blockchain's impact is contingent on digital infrastructure, literacy, and regulatory support. The findings support theoretical frameworks such as Digital Trust Theory, Risk Management Theory, and FinTech Adoption Theory, emphasizing that blockchain is not merely a technological innovation but a strategic tool for market integrity. Practical recommendations include phased adoption, regulatory alignment, investor education, and infrastructure development to maximize blockchain's benefits. Overall, integrating blockchain into Indonesia's digital bullion market offers a robust, innovative approach to mitigating fraud risks while strengthening transparency and accountability, providing valuable insights for both policymakers and industry stakeholders. Future research should focus on empirical validation, performance metrics, and comparative analyses with other regional markets to further refine blockchain implementation strategies.

Acknowledgement

The authors would like to thank the academic and research community whose published works on blockchain technology, digital finance, market transparency, risk

management, and digital bullion markets provided valuable insights for this conceptual literature review. The authors also acknowledge PT Pegadaian (Persero) for providing financial support for the publication of this research.

Author Contribution

The author was solely responsible for the conceptualization, literature search and selection, data synthesis, thematic analysis, interpretation of findings, development of the conceptual framework, and writing and revision of the manuscript.

Funding

This research received no specific research funding. However, PT Pegadaian (Persero) provided financial support for the publication of this research.

Ethical Review Board Statement

Not available.

Informed Consent Statement

Not available.

Data Availability Statement

No primary datasets were generated or analyzed in this study. The study is based on a conceptual synthesis of published literature retrieved from the Scopus and Web of Science databases. The sources analyzed are publicly accessible through the respective databases and publishers.

Conflicts of Interest

The author declares no conflict of interest related to the research, authorship, or publication of this article.

Declaration of Generative AI Use

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