Revolutionizing Global Trade: Blockchain for Transparent and Tamper-Proof Supply Chains

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Abstract:
As the volume and interconnectedness of global trade rise, there are growing challenges related to traceability, counterfeiting, regulatory compliance, and system inefficiencies. Blockchain technology offers a transformative solution for these challenges by providing decentralised, tamper-proof, and transparent ledgers that enable real-time visibility and trusted collaboration across stakeholders. This article explores the practical applications of blockchain in sectors such as food, pharmaceuticals, and cross-border logistics. It highlights how smart contracts, immutable records, and digital product passports enhance trust, automate compliance, and reduce fraud. It also addresses key adoption challenges, including integration, governance, and legal ambiguity, and offers strategic insights into how blockchain can reshape the future of global trade.

Keywords: Blockchain Technology, Supply Chain Transparency, Smart Contracts, Trade Compliance, Counterfeit Prevention.

1. Introduction

Within the current globalised world, trade involves a vast and intricate network of manufacturers, suppliers, logistics companies, customs authorities, distributors, and retailers, all interacting across countries, languages, and technological platforms (Ahmed et al., 2024). This makes global trade complex; a complexity level which is exacerbated by the fragmentation of information systems that limits visibility and transparency across the supply chain (Chang et al., 2020). Trade data are usually stored in organisational silos while trade processes are heavily reliant on paper-based documentation and manual reconciliation (Bondarenko, 2023). As a result, the visibility into the movement, condition, and origin of goods remains limited, hindering efficient decision-making and increasing vulnerability to supply chain disruption.

A major challenge facing global trade as a result of the complexity in global supply chains and reliance on fragmented paper-based systems is the proliferation of counterfeit goods. According to a new OECD–EUIPO report, based on the latest available data, counterfeit and pirated goods accounted for $467 billion in global trade in 2021, representing 2.3% of total global imports (OECD, 2024). Another key challenge as a result of reliance on traditional documentation systems in global trade is regulatory compliance. For instance, industries such as food and pharmaceuticals face delays of up to six days or more in tracing the source of contamination or faulty products across their global supply chains, which puts public health and safety at risk (Tibeb et al., 2024). To address these challenges, international regulatory frameworks such as ISO 28000 (Supply Chain Security Management), the U.S. Food Safety Modernisation Act (FSMA), and the EU Due Diligence Act are becoming increasingly strict, as countries seek to secure their supply chains and protect their population. These frameworks require companies to maintain detailed, auditable records across complex, multi-party networks, which is labour-intensive and expensive.

Blockchain technology, distributed ledger technology (DLT), has emerged as a viable solution to these key challenges (Al Shamsi, 2024). Blockchain technology offers decentralised, immutable, and transparent digital ledger of transactions, eliminating the need for intermediaries and eliminating the risk of individuals tampering with data or potential data loss (Ahmed, 2025). The technology offers a trail across the supply chain, making it easier to address counterfeiting and facilitating compliance. This article investigates how blockchain can revolutionise global supply chains by ensuring transactions are traceable, transparent, and tamper-proof. The article also explores real-world implementations across sectors, evaluates the challenges of adoption. Here are the Key objectives:

i.Evaluate the effectiveness of blockchain in modern trade operations

ii. Explore the role of blockchain in reshaping supply chains ecosystems
iii. Explore key use cases of blockchain in global supply chains
iv. Analyse the key challenges hindering the adoption and implementation of blockchain in the global supply chain

2. PROBLEM STATEMENT

While the global trade is rapidly digitising, a major part of supply chains still operates on outdated infrastructure, heavily reliant on siloed enterprise resource planning (ERP) systems, paper documentation, and spreadsheets (Agbelusi et al., 2024). These fragmented systems hinder real-time end-to-end visibility, requiring labour-intensive manual reconciliation, which increases the risk of errors, data duplication, fraud, as well as delays. This leads to inefficiencies that result in delivery failures, compliance penalties, or reputational damage. With a lack of real-time traceability across the supply chain, companies often struggle to verify the origin of raw materials, confirm ethical sourcing practices, or authenticate environmental, social, and governance (ESG) credentials. In industries such as fashion, electronics, and agribusiness, supply chains span multiple geographies and intermediaries, making it difficult to track goods in motion, detect tampering, or validate claims, providing breeding grounds for counterfeiting. Furthermore, malicious actors exploit system gaps to commit customs fraud, engage in inventory manipulation, or impersonate legitimate vendors, adding further layers of operational and financial risk.

Blockchain is increasingly viewed as a transformative solution. Its core features, such as immutability, decentralisation, and consensus-driven validation, enable secure data sharing, automated process execution, and end-to-end traceability across the entire supply network. This paper evaluates blockchain's potential to address these systemic inefficiencies and build trust in global trade.

3.0 EFFECTIVENESS OF BLOCKCHAIN IN MODERN TRADE OPERATIONS

3.1 Enhanced Traceability and Real-Time Monitoring

Verifying the authenticity of products from source to shelf is a critical challenge that blockchain technologies are solving**.** Blockchain technology achieves this by significantly enhancing traceability within the global supply chains as it creates a transparent, chronological ledger of every transaction and interaction (Rejeb et al., 2021). By ensuring a tamper-proof record in real-time, blockchain technology ensures no participant can alter historical data without consensus from the network (and a record of the changes) (Centobelli et al., 2022). Thus, this technology, combined with the Internet of Things (IoT) devices like temperature sensors and GPS trackers, can record the location and environmental conditions of products during transit. Furthermore, integration with QR codes or tags linked to blockchain entries enables consumers and regulators to scan products, viewing their entire journey, from the source point to shelves, enabling verifiable authenticity and compliance (Oriekhoe et al., 2024). IBM Food Trust is an example of a blockchain-based platform that enables businesses to track and verify food products' supply chain, enhancing transparency, traceability, and efficiency.

3.2 Tamper-Proof Records and Anti-Counterfeiting

Counterfeiting is a critical challenge resulting to losses of $467 billion in global trade. Here, businesses are utilising the immutability feature of blockchain to ensure tamper-proof records that cannot be altered. This tamper-proof feature almost completely deters fraudulent activities such as invoice manipulation, customs misreporting, and product substitution (Potdar et al., 2023). Already, sectors like pharmaceuticals are utilising blockchain secure product verification through unique digital identifiers (Gomasta et al., 2023). According to Uddin (2021), MedLedger, a consortium-backed blockchain platform, helps combat counterfeit drugs by creating a validated chain of custody across drug manufacturers, wholesalers, and pharmacies, in line with the U.S. Drug Supply Chain Security Act (DSCSA).

3.3 Smart Contracts for Automated Compliance

In global trade and supply chains, there is a need for smart contracts that autonomously trigger the release of payments, initiate customs filings, or update inventory systems (Oluwaferanmi, 2025). This automation boosts efficiency by eliminating the need for manual approvals or intermediaries, thereby reducing processing time, operational overhead, and opportunities for fraud. To boost the reliability of these smart contracts, companies are utilising a smart contract blockchain structure, to improve the authenticity and permanence, and hence the reliability of these contracts (Oluwaferanmi, 2025). This eliminates human errors in documentation across

supply chains while enabling scalability, which supports just-in-time delivery through digital trade finance trends.

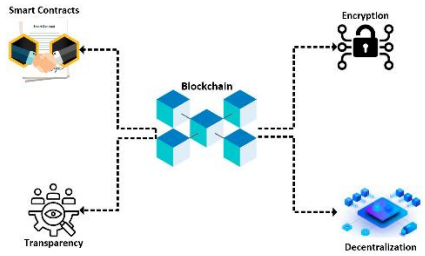

Figure 1: Blockchain transparency (Theodorakopoulos et al., 2024)

4.0 ROLE OF BLOCKCHAIN IN RESHAPING SUPPLY CHAIN ECOSYSTEMS

4.1 Transparency and ESG Reporting

In the world today, the consumer base is becoming increasingly conscious of environmental and social issues creating a need for corporate accountability and sustainability, as businesses try to attract customers (Noble, 2023). Blockchain offers an effective tool for enabling on corporate accountability and sustainability by embedding Environmental, Social, and Governance (ESG) data into supply chain records (Leogrande, 2024). Businesses are able to tag products with carbon emissions data, water usage, or renewable energy credentials, ensuring this information travels with the goods across borders. Blockchain's immutability ensures that sustainability claims are verifiable and auditable in real time. Companies can also record labour conditions, human rights certifications, and compliance scores, which are especially important for reporting under regulations such as the EU Corporate Sustainability Reporting Directive (CSRD).

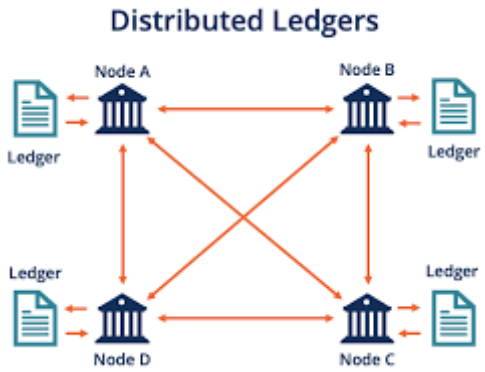

Figure 2: Shared Blockchain ledger (CFI, 2024)

4.2 Resilience in Crisis Situations

Blockchain's decentralised nature significantly strengthens supply chain resilience, particularly during major disruptions such as pandemics, natural disasters, or geopolitical conflicts. For instance, as presented by Shen et al (2023) during the COVID-19 pandemic, blockchain systems were used to track and verify the authenticity of personal protective equipment (PPE), vaccines, and test kits, minimising counterfeit infiltration in emergency procurement channels (Chauhan et al., 2021). Furthermore, in situations where traditional logistics channels were disrupted, such as port closures, trade embargoes, or cyberattacks, blockchain offers a redundant, available, and tamper-proof system for managing shipment data and rerouting supplies. Blockchain allows dynamic supplier revalidation, instant tracking of alternative logistics paths, and resilience modelling based on real-time risk analytics. This boosts supply chain responsiveness while also supporting disaster recovery plans and business continuity strategies in volatile global markets.

5.0 KEY USE CASES OF BLOCKCHAIN IN GLOBAL SUPPLY CHAINS

5.1 Food Safety and Agricultural Trade

As a result of agricultural product perishability and health risks associated with contamination, the food supply chain is uniquely vulnerable. Thus, an end-to-end traceability is critical to isolating affected products, preventing widespread recalls, and ensuring compliance with regulatory frameworks. Here, blockchain offers

a reliable digital record of each stage in a product's journey, from harvest to consumption. Key attributes such as harvest dates, pesticide usage, temperature during transport, and storage conditions can be recorded and shared in real-time among stakeholders. The IBM Food Trust platform exemplifies the power of blockchain in food safety (Chen and Long, 2021; Markovic et al., 2020).

5.2 Pharmaceutical Authentication

Pharmaceutical products are among the most counterfeited products. the global market for counterfeit drugs is estimated at $200 billion annually, according to the International Bar Association (2025). To address these challenges, regulatory frameworks such as the Drug Supply Chain Security Act (DSCSA) in the United States and the EU Falsified Medicines Directive (FMD) require end-to-end visibility and verification across the drug lifecycle (Naughton et al., 2025). Blockchain platforms such as MediLedger and SAP Pharma Ledger fulfil these mandates by providing a decentralised system that records the origin, batch numbers, expiration dates, and movement of pharmaceuticals in real-time (Thakur, 2023). Blockchain's ability to prevent entry of illegitimate drugs into the supply chain is transformative. It enables verification of serial numbers, detection of diversion into grey markets, and execution of targeted recalls without affecting entire batches.

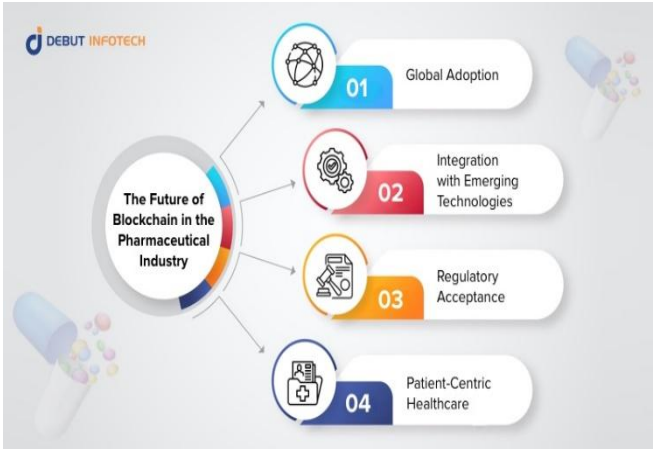

Figure 3: Blockchain in Pharmaceutical (Debutinfotech, 2023)

5.3 Cross-Border Logistics and Trade Finance

To enable seamlessness and facilitate the scale of global trade, there is a need for coordination across borders, often involving complex documentation, customs procedures, and financial settlements. Traditional paper-based bills of lading can take days to transfer between parties, resulting in delays. However, while using blockchain-based electronic bills of lading (eBLs), there is an instant transfer of ownership and document validation, significantly improving efficiency and reducing risk (Singh, 2024). In trade finance, blockchain platforms such as We.Trade and Marco Polo reduce fraud in letters of credit, factoring, and invoice financing by providing a transparent, immutable audit trail (Aránguis et al., 2021). These systems not only lower financing risk but also expand access for small and medium enterprises (SMEs) in emerging markets.

6.0 CHALLENGES IN ADOPTION AND IMPLEMENTATION

6.1 Technical Integration and Scalability

Integrating blockchain with legacy supply chain technologies such as ERP (Enterprise Resource Planning) systems and customs infrastructure poses considerable challenges (Dasaklis et al., 2021). Many of these legacy systems were not designed for real-time data synchronisation or decentralised validation, requiring significant reengineering. Thus, there needs to be investment in technologies as well as human resources with the skills to operationalise the technology. Addressing the integration issues will improve operational efficiency, enable workflow automation, and ensure easier compliance.

6.2 Legal and Regulatory Barriers

The legal landscape for blockchain-based trade systems remains fragmented as it's still in the early phase. As presented by Chaisse and Kirkwood, J. (2022), while smart contracts are enforceable in some jurisdictions, many countries lack clear legal frameworks for their recognition or dispute resolution. There is also tension between blockchain's immutability and privacy regulations such as the General Data Protection Regulation (GDPR), which grants individuals the right to have their data erased. National variations in evidence laws,

audit access, and digital identity frameworks further complicate cross-border implementation. Moreover, customs and tax authorities in many developing nations lack the technical infrastructure or legal mandate to interface with blockchain systems, slowing adoption in key trade corridors.

6.3 Cost, Complexity, and ROI Concerns

Implementing blockchain solutions requires significant initial investment in infrastructure, staff training, and organisational change management. These costs are particularly burdensome for SMEs, which often lack the technical expertise or financial capacity to participate in blockchain networks. The shortage of skilled blockchain developers and data governance professionals adds to implementation delays. Finally, most successful deployments require consortium-based collaboration among supply chain partners, competitors, and regulators, which can be difficult to coordinate due to differing incentives, legal obligations, and trust levels.

7.0 CONCLUSION

Blockchain is redefining how global supply chains are managed. This is because the technology enables secure, transparent, and real-time data sharing, and it addresses persistent issues of traceability, fraud, and compliance inefficiencies. Use cases across food safety, pharmaceutical authentication, and luxury goods demonstrate its versatility and impact. However, realising its full potential requires overcoming significant barriers, including interoperability, regulatory uncertainty, and stakeholder alignment. As digital trade evolves, blockchain stands as a foundational technology for creating resilient, ethical, and data-driven supply ecosystems.

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