Blockchain-based Supply Chain Traceability: Legal Effectiveness and Consumer Rights Protection in Cross-border E-commerce

**Abstract**

Blockchain technology is considered another subversive technological innovation that has permeated into cross-border e-commerce which helps improve the traceability of the supply chain. Given this digital era, consumers and businesses want brands to guarantee the authenticity of their products while supply chain participants seek better visibility and responsible sourcing to minimise disputes. There are challenges of cybercrimes and breaches of data privacy that need to be considered to secure data. This research study will analyse this Blockchain technology's practical and legal effectiveness in promoting a secure global trading environment. Employing a qualitative research method, this study relies on secondary sources like case studies, academic literature, articles and journals to analyse the application of Blockchain technology in expanding cross-border e-commerce to ensure consumer trust in global trade. Using the qualitative research methodology and drawing from real cases such as Walmart, Amazon and IBM, the study explores the applicability and efficacy of the role of Blockchain in improving supply chain transparency. This research assesses the practical and legal efficacy of Blockchain technology in enhancing transparency in supply chain management as well as safeguarding consumers in the global e-commerce setting. The key findings of the study reveal the legal recognition and enforceability of Blockchain technology such as smart contracts. The study illustrates how the application of Blockchain technology has been effective in enhancing consumer trust and safeguarding them against data privacy breaches. A comparative analysis is used to understand how various nations have tailored approaches to use Blockchain technology. Despite the existence of legal challenges and the different regulatory frameworks across the globe, data privacy is perceived as a major concern. In this regard, the study concludes by highlighting the need for strengthening the regulations of this technology to optimise its potential in the cross-border e-commerce industry. The research results reveal how the legal enforceability of smart contracts and the use of decentralised ledgers have been effective in addressing major concerns like data breaches and information asymmetry. The study explores both the limitations and opportunities of this innovative technology in establishing that Blockchain technology is reshaping the global supply chains, with implications for consumer protection and legal compliance.

**Keywords:**

Supply chain; Blockchain technology; cross-border e-commerce; consumer trust, traceability

# Introduction

Blockchain is an empowered technology that contributes to improving the efficiency of supply management through innovative management practices which expand cross-border e-commerce (Liu & Li., 2020). The term ‘Supply Chain Traceability’ refers to the ability to track the origin, movement, and status of goods and materials throughout the supply chain—from manufacturer to consumer. Further, Cross-border E-commerce denotes the online selling and purchases of goods or services between businesses or consumers in different countries (Zhou & Liu, 2022; Huang et al., 2023). It involves international transactions, different legal systems, and potential consumer risks. The cross-border e-commerce supply chain and logistics channel are being driven by Internet-based advanced information technologies (Zhou & Liu, 2022). In this context, the study focuses on tracking supply chains in global e-commerce based on Blockchain technology.

Blockchain is a decentralised, digital ledger that records transactions across many computers. When applied to supply chains, Blockchain can increase transparency, prevent fraud, authenticate product origin and improve logistics efficiency while the application may encounter challenges (Monrat, Schelén & Andersson, 2019). For this purpose, the study will be divided into the following sections. However, given this technology maintains transactions on encrypted databases, sensitive and confidential information about consumers such as their financial statements is routinely transferred via e-commerce which raises major concerns about cybercrimes (Albshaier, 2023). A data breach is a significant challenge that not only impedes the performance of the affected enterprise but also falters the confidence and trust of eh affected consumers in the platform (Albshaier, 2023). Nonetheless, the application of Blockchain technology in global trade has also been equally useful in detecting fraudulent activities in transactions with its capability of storing detailed records of all the data.

The present research study aims to evaluate the efficacy of applying Blockchain technology in improving supply management and promoting global digital commerce. It posits that despite numerous challenges relating to the security of e-commerce transactions globally and the potential threat to the faith and confidence of customers due to growing cybercrimes, the application of Blockchain technology contributes to a mutual trust trading network addressing security problems in e-commerce while trading and promotes visibility, transparency, thus, effectively, resolving issues like information asymmetry and information opacity. For this purpose, the study shall analyse the legal efficacy of the Blockchain process acknowledging its role in supply chain transparency in the international digital commerce industry. The study shall also determine how this advanced technology can enhance consumer trust while addressing potential challenges associated with the Blockchain process using relevant case study examples.

Research questions

To explore the role and implications of Blockchain in global e-commerce, the study is guided by the following research questions:

1. How is Blockchain technology improving traceability in global supply chain management?
2. How does Blockchain technology safeguard consumer rights in cross-border e-commerce?

# Legal Effectiveness and Recognition of the Blockchain Processes in Global Trade or E-commerce

Supply chain transparency is indispensable for contemporary business and Blockchain technology is a promising solution to improve transparency in supply chain management. According to Payandeh et al, (2025), supply chain refers to the ability to trace the journey of a product throughout the supply chain from the source to the end consumers which may raise concerns for enterprises and the government. This is because the supply chain is not merely about regulatory compliance or optimising the effectiveness of the business operations rather it is about ensuring that the product maintains the expected standards and business fosters sustainable practices (Payandeh et al, 2025). Against this backdrop, the introduction of Blockchain technology is perceived as an effective remedy in addressing this concern (Sunny et al., 2022). The development of the Blockchain process and its application within supply chains is essential for enhancing transparency, trust and efficiency.

## Role of Blockchain technology in supply chain management and global trade- the use of smart contracts

The importance of Blockchain technology in the supply chain is underpinned by its strengths such as smart contracts that transform traditional supply chain processes in terms of increased visibility and traceability. According to Chang, Iakovou and Shi (2020), a smart contract is a program inside a Blockchain comprising of set of rules that outlines rights, obligations and conditions that are consented to by parties to the smart contract. For instance, Walmart uses smart contracts implementing a Blockchain-based system to enhance safety of food products. Chang, Iakovou and Shi (2020), further highlight the benefits of using Blockchain technology in enhancing supply chain management. Smart contracts are cost-saving; the automation and sel-execution features of these contracts ensure speed and accuracy of terms, conditions and transactions which also saves time; Smart contracts enhance transparency for their accessibility to all relevant parties which eliminates any scope for miscommunication and visibility builds trust in the technology; last, this Blockchain-base technology encrypts every transactions storage which strengthens the security of these data since encrypted data cannot be modified easily.

## Legal position of smart contracts – are they deemed as contracts enforceable by law?

Smart contracts are deemed a legally enforceable contract if they satisfy the elements of a contract, which includes an offer, an acceptance, intention to legally bind the contract and consideration. It is further argued that smart contracts are self-enforcing when the contract has been formed and stored on a Blockchain. On meeting contractual obligations, the assets will be exchanged as per the terms and conditions of the contract. Hence, smart contracts cannot be said to be legally invalid or unenforceable. In the US, several states have passed Blockchain legislation that explicitly recognises smart contracts to have legally enforceable obligations (Durovic & Lech, 2019). For instance, Arizona Revised Statutes, Title 44 Trade and Commerce, §44-7601C acknowledges the existence of smart contracts in commerce and that a contract will become unenforceable legal enforceability only because it contains smart contractual terms. Likewise in Tennessee Code, Title 47 (Commercial Instruments and Transactions) §47-10-201, the smart contract refers to a computer program that is executed distributed, electronically, decentralised, replicated and shared ledger that assists in automatic transactions. As per §47-10-202, a cryptographic signature is generated and stored through ledger technology which is identified as an electronic signature. A contract secured through distributed ledger technology like smart contracts exists in commerce that shall be legally enforceable. In other nations like Malaysia, the Contracts Act 1950 governs the enforceability of contracts and considers all agreements as contracts if they meet all contractual elements like offer, acceptance, consideration, intention and free consent of the parties. Additionally, the Electronic Commerce Act 2006 [ECA] acknowledges electronic signatures and smart contracts as legally valid and enforceable agreements in both writing and electronic signature forms, which fundamentally extends to the Electronic transaction and e-commerce provisions using smart contracts.

Comparative analyses of Blockchain application under different legal frameworks globally

Legislators and consumers have major concerns about data privacy breaches and customer privacy. While the General Data Protection Regulation [GDPR] has offered a global standard for safeguarding consumer data country-specific legal regimes for Blockchain technologies are widely different (Treiblmaier & Sillaber, 2021). For instance, countries like the People’s Republic of China [PRC], the United States and the UK all have tailored approaches (Kaal & Dell'Erba, 2017). The US relies upon multi-agency to supervise consumer protection while China is more focussed on national security with centralised control through agencies like banks (Triveni, Jaikishen & Sanjana, 2024). The UK emphasises financial stability and anti-money laundering compliance using the Crypto Assets task force.

# Protection of Consumers' Rights and Interests

Blockchain enhances product safety recalls or allows consumers to seek dispute resolution to address any violation of their rights or interests. The traditional dispute-resolution process has its limitations which is an expensive, cumbersome and time-consuming process, particularly, in cross-border transactions, jurisdictional issues and the legal systems of different nations often add more complexity in seeking redress for aggrieved consumers (Zuo et al, (2024). Although it is argued that arbitration is deemed a flexible alternative dispute mechanism. However, Zuo et al, (2024) further stress the limitations of arbitration as an effective means to resolve cross-border e-commerce disputes. First, arbitration is not cost-effective and neither is effective in resolving disputes meeting the needs of the rapidly developing global e-commerce market. Second, the transparency and fairness of arbitration are limited by the procedures and rules of different arbitration institutions. Thus, the lack of unified standards has significantly reduced the efficacy of arbitration in resolving cross-border e-commerce disputes.

Against this backdrop, online dispute resolution [ODR] are decentralised platforms that overcome the challenges associated with traditional dispute resolution mechanisms. Blockchain technology with its unique decentralised features provides a fair, efficient and transparent e-commerce dispute resolution process. For instance, in case of disputes arising in international digital commerce transactions, smart contracts automatically determine and execute all the relevant measures based on the pre-set rules (Zuo et al, 2024). These include rules relating to the deadline for providing dispute resolution process, evidence, and calculation method of compensation are all pre-set for resolving any disputes. Further, on a cross-border e-commerce platform when a client complains about not receiving goods, the smart contract first checks the consumer logistics tracking the data. Then it confirms if the goods have been delivered or if the logistics status is normal. In case there is a dispute in logistic data, the smart contract will automatically process a refund based on pre-set rules. This ensures that any disputes arising can be resolved quickly and efficiently with less human intervention.

# Analysing how this technology enhances consumer trust and protection

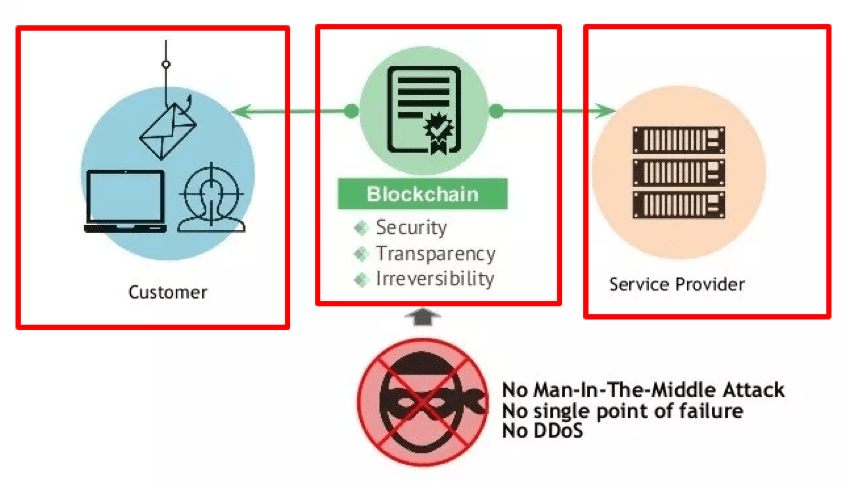


Figure 1: Blockchain technology is secure and transparent  
Source: (Smart Insights, 2019)

As observed on fig 1, Blockchain technology enhances consumer trust by increasing traceability, security, irreversibility and accountability of supply chain management offering product tracking and quality assurance to international digital commercial transactions. The adoption of Blockchain technology has revolutionised global industry standards enhancing both product safety and consumer trust.

Offering end-to-end transparency and security transparency

Blockchain designs and tracking abilities offer a full audit trail that can improve transparency in supply chain management. Consumers can always trace every product moved through the authorised Blockchain-backed platforms and may either reject or validate the product (Chang, Iakovou & Shi, 2020). Walmart mandated to use Blockchain-based supply chain system for all its suppliers of leafy greens for its time-saving feature that can track products in relatively lesser time.

Accountability

The capability of Blockchain to record ownership transfer, asset governance, safety requirements and legalities in real which helps remove any form of ambiguities and enhance accountability. Additionally, Chang, Iakovou and Shi (2020) point out how such a system can offer low procedural expense and real-time data transparency which is likely to offer a high rate of fair judgements while resolving disputes quickly. Further, the ability of smart contracts to trigger fines or compensation in case of non-compliance with pre-set terms makes Blockchain technology preferable to traditional dispute resolution processes.

Combating counterfeiting & illegal activities

Blockchain technology is highly secure as each participant who enters into the Blockchain network has a unique identity connected to his or her account. The Blockchain makes it challenging for hackers or cybercriminals to hack the system. Monitoring and regularly tracking products on the Blockchain can ensure the integrity of the supply chain process.

# Examples of Case studies:

Since e-commerce has transformed cross-border purchases, Blockchain is revolutionising the e-commerce industry to make transactions for both companies and customers safer and faster. However, Sharma and Kumar (2021) state that not all Blockchain technology is the same- there are four various forms of Blockchain technology commonly used in the e-commerce industry- Bitcoin, Ethereum IBM and Custom. Ethereum and Bitcoins are cryptocurrencies that are the driving force of this Blockchain technology and bitcoins have been embraced by leading corporates like Tesla, Google, Spotify and Microsoft. IBM offers Blockchain technology that is incredibly useful for retail giants like Walmart. Custom is the most flexible Blockchain solution for the digital commerce industry as it allows companies to customise their exclusive requirements with the help of Blockchain Development Company which is profitable in the long run.

IBM

IBM has leveraged Blockchain technology in its supply chain process by improving security, efficiency and transparency leading to increased consumer trust and cost savings. Given that supply chain-related data is not always available, trusted or visible, IBM Blockchain technology helped supply chain partners to share their trusted information using permissioned Blockchain solutions (Stringer & Treiblmaier, 2024). Blockchain technology builds consumer trust and promotes innovative supply management practices. First, it secures cross-border transactions with an immutable and shared ledger that will provide real-time and end-to-end visibility to consumers. In regards to strengthening supply management, the IBM Blockchain technology provides a digital supply chain identity for suppliers that helps build relationships with multiple buyers (Stringer & Treiblmaier, 2024). It is advantageous because it helps them avoid redundant submission of the same information and is less time-consuming, additionally, artificial intelligence [AI] and automation have been effective in offering resiliency and sustainability to supply chain management.

Walmart

In the supply chain, retail giants like Walmart have adopted Blockchain technology. According to a statistical report, the company has the highest shareholding of 66 per cent for their organisational work (Sharma & Kumar, 2021). This company has been implementing IBM’s supply chain management which is the hyper ledger fabric platform that supports the supply chain operation of the company (Sharma & Kumar, 2021). Walmart monitors all supply chain transactions and suppliers while allowing consumers to validate the source before making any purchase using this technology.

Amazon

The digital supply chain is the backbone of this e-commerce giant illustrating an excellent technological integration where the hardware and software seamlessly connect every link of the chain from the suppliers to the consumers (Stringer & Treiblmaier, 2024).

# Legal challenges

Regulatory and legal challenges exist for the worldwide adaptation of Blockchain in global supply chains. The key legal challenges have been identified by the World Economic Forum in 2018.

Distributed laws and jurisdiction

As each node of the Blockchain ledger is potentially located across the globe, the ledgers do not have any identified location for every transaction that is made. This often creates confusion while determining the jurisdiction of the Blockchain (Chang, Iakovou & Shi, 2020). Also, there is no uniformity in the applicability of laws since every nation has its jurisdiction and laws. Pre-set rules regarding deciding matters in disputes can be an effective means to address this complexity associated with Blockchain technology.

Legal status of Blockchain Transactions

To ensure the successful deployment of smart contracts and transactions, it must demonstrate legal validity across global jurisdictions. The legally binding nature of Blockchain technology lacks uniformity and varies across jurisdictions. Although Blockchain technologies have received recognition, their legal status remains unclear and a uniform recognition worldwide. For instance, in Ukraine, there are no legislative frameworks to regulate cryptocurrencies in Ukraine. This lack of clarity is deemed as a major concern as it may create uncertainty for individuals and businesses engaged in Blockchain transactions which in turn, may potentially prevent them from the benefits of this advanced technology.

Breach of data privacy

A breach of confidential data is one of the most common and significant challenges in Blockchain-based transactions. Blockchain transactions are pseudonymous which means that they are not directly connected with the identities of customers (Bron, 2023). Additionally, their immutable and transparency-enhancing abilities prevent any transaction from being altered or removed once the transaction is recorded in the ledger (Bron, 2023). However, this Blockchain technology also introduces novel risks such as theft or loss of private keys, any flaws in smart contracts or misuse of Blockchain technology. Some of the privacy breach in Blockchain technology is enumerated below:

*Bitcoin Savings & Trust [BST] Ponzi scheme case*

In this case, the operator of BST was charged by the US Securities and Exchange Commission [SEC] for defrauding investors of over 700,000 Bitcoins (Cole, 2024). This case highlighted the potential misuse of this advanced technology by engaging in illegal activities and the need for robust regulatory measures.

*Collapse of Mt. Gox Bitcoin Exchange*

In 2014, the collapse of Mt. Gox led to the loss of 850,000 Bitcoins which resulted from a hacking incident (Cole, 2024). This case underpinned the security risk related to Blockchain transactions and the necessity of undertaking cybersecurity measures.

*Poly Network Hack (2021) case*

In 2021, the Poly Network, a cross-chain DeFi platform was subjected to a $611 million cyber hack but the hacker returned all the stolen money after communicating openly with the company’s team (Cole, 2024). However, this case illustrates the significance of open communication channels between affected projects and hackers.

*The Dao attack (2016) case*

In 2016, the DAO, a decentralised autonomous organisation that adopted Ethereum Blockchain technology was subjected to a cyberattack owing to some flaws in their smart contract code. The cybercriminal had drained off about $50 million worth of Ether and it caused Ethereum Blockchain to recover the stolen funds (Cole, 2024). This incident underscored the significance of robust monitoring, reviewing and auditing before deploying smart contracts. It further stresses on having mechanisms in place within the Blockchain systems to prevent any unforeseen vulnerabilities.

*DNS Hijacking case*

This 2017 cyberattack was significant as it targeted various cryptocurrency exchanges and wallets enabling the cybercriminals to redirect users to malicious websites. This way the hackers stole their private keys and login credentials resulting in the theft of all the user’s funds (Cole, 2024). This incident underpins the need for strong security measures and regulatory compliance mechanisms internally to facilitate crypto exchanges. The incident also emphasises securing online identities and employing two-factor authentication to safeguard digital assets.

# Mitigation of challenges by ensuring product safety and gaining consumer confidence

Given security is a major challenge with data breaches and fraud being substantial issues, strengthening consumer trust and employing robust cybersecurity methods are fundamental for the further development of digital commerce. Technological advancement and the evolution of consumer behaviour led to rapid growth in e-commerce have been offering both opportunities like Blockchain technology that ensures security and enhances traceability in supply chain management. It has also challenges for businesses and customers in this digital era that must be mitigated to ensure the safety of products and gain consumer trust and confidence in Blockchain technology. The following measures substantially contribute to ensuring data privacy and security are safeguarded against cybercrimes.

*Encryption and Data Security*

Encryption denotes the privacy of sensitive data that is transformed into an indecipherable format for unknown entities. In an e-commerce context, the user provides personal data or payment details on a website, and encryption protocols such as Transport Layer Security or Secure Socket Layer (TLS/SSL) are deployed to translate the data before they are transmitted over the internet. Encryption algorithms also provide robust security against any unauthorised access which at least lowers the potential risk of identity theft and a data breach to prevent incidents like the DNS Hijacking case. Additionally, TLS/SSL certificates act as a visual indicator for users to understand that websites are secure which means users can see a green address bar in their browser that indicates their data is encrypted and protected. This visible demonstration of encryption protocols can assure customers that their data is safe and is an effective means of gaining the trust of consumers on cross-border e-commerce transactions that use Blockchain technology. This is a safe mechanism for e-commerce transactions carried out by consumers on public networks which are generally vulnerable to interception by hackers. However, with encryption protocols, even if the data is hacked, it shall remain unreadable to hackers.

Access control and secured authentication

A robust authentication mechanism is critical for preventing any unauthorised access to customer accounts and confidential data while making international commercial transactions. Some key verification mechanisms that can ensure security using biometrics. The biometric system includes features like face recognition, fingerprints, voice recognition or iris scans to verify user identity, strong passwords offer highly secured authentication methods. As access control measures, secure protocols such as virtual private networks or VPNs and restrict accessibility to only authorised individuals can protect against data breaches.

Data privacy and legal compliance

Legal compliance with data protection frameworks such as the General Data Protection Regulation or GDPR is crucial for protecting customer data in global trade. These regulations have been significant as they help businesses avoid reputational damage and financial penalties resulting from any non-compliance and data breaches (Albshaier, Almarri & Hafizur Rahman, 2024). Additionally, the combination of Blockchain with innovative technologies like a three-layered (network, perception and service layer) Internet of Things (IoT) infrastructure can be applied to ensure sensitive information shared is encrypted and secured against any data breach (Treiblmaier & Sillaber, 2021). The legal status of Blockchain technology will not only strengthen data security measures but will also enforce mandatory reporting obligations to avoid any potential risk of a data breach that may occur.

# Conclusion

The growing reliance on e-commerce transcending national borders combined with Blockchain technology has revolutionised cross-border trade and online transactions. The findingsevaluated the legal efficacy of Blockchain-based records and processes legally recognized in international trade and e-commerce.For instance, it identified the enforceability of smart contracts or if Blockchain records are admissible in court. The research established how Blockchain traceability helps protect consumers by utilising a digital ledger which offers security to decentralised selling and purchasing platforms within the e-commerce. As demonstrated in this research study, the incidents of cyberattacks only highlight the significance of cybersecurity in this digital era where e-commerce is central to the digital business landscape. The use of Blockchain helps improve supply chain traceability and secures sensitive data of consumers and companies ensuring data integrity through advanced cryptographic methods. Thus, this discussion illustrates the complexities of e-commerce security while emphasising the effectiveness of the innovative Blockchain technology as a viable means to strengthen data security measures ensuring a more reliable and safer online experience for both businesses and consumers.

Disclaimer

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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