

Blockchain Solutions for Authenticity and Combatting Counterfeiting in the Spirits Industry - Exploring the Roles of Information Asymmetry and Transaction Cost Theory

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Abstract:

This article explores the role of blockchain technology (BCT) in combating authenticity issues and counterfeiting within the global spirits industry. Anchored in Information Asymmetry Theory and Transaction Cost Theory, the study addresses how blockchain can mitigate prevalent problems related to product authenticity, fraud, and associated economic losses. The rapid expansion of the spirits market, particularly in emerging economies, coincides with a significant rise in counterfeit products, posing health risks, economic harm, and brand damage. Traditional authentication methods, such as physical and chemical verifications, remain fragmented, costly, and susceptible to fraud, resulting in substantial transaction costs.

Through qualitative research involving semi-structured interviews with representatives from technology providers and spirits producers, the study examines blockchain's efficacy as a tool for signalling authenticity and reducing transaction costs. Findings indicate that blockchain enhances product authenticity by providing immutable, transparent records accessible throughout the supply chain, effectively reducing information asymmetries and transaction-related expenses. Producers see significant potential for blockchain solutions, especially for premium and collectible products, with applications extending beyond anti-counterfeiting to customer relationship management, secondary market control, and consumer engagement.

However, the research identifies barriers to broader adoption, including high implementation costs, regulatory uncertainty, limited consumer awareness, and technological complexity. Despite these challenges, blockchain emerges as a promising hybrid mechanism capable of simultaneously improving operational efficiency and strengthening consumer trust.

The study concludes that successful blockchain integration will depend heavily on strategic alignment among producers, technology providers, and regulatory bodies. It recommends future research focusing on consumer perceptions, quantifiable economic impacts, and regulatory integration. Ultimately, blockchain offers a transformative approach to authenticity assurance and anti-counterfeiting in the spirits sector, provided it is implemented in a targeted and strategically coherent manner.

Keywords:

Spirits Industry, Counterfeiting, Information Asymmetry, Transaction Cost Theory, Blockchain Technology

1. Introduction

The global spirits industry has grown significantly over recent decades, now constituting approximately half of total alcohol consumption worldwide [1,2,3]. This expansion reflects rising spirits consumption across diverse markets, driven notably by volume growth in emerging economies such as China and India [4]. Unlike beer and wine, whose global consumption trends have shown stagnation or decline, spirits continue to gain market share [3].

Accompanying this growth, however, is a significant rise in the prevalence of counterfeit and illicit spirits, posing substantial health, economic, and reputational risks. Illicit spirits account for a considerable share of the market globally, with estimates ranging from more than 20% [5,6] to over 40% in certain regions [7,8,9]. These products endanger human health [10,11,12], inflict economic losses on legitimate businesses [13,14], erode tax revenues for governments [15,16,14], and undermine consumer confidence in otherwise strong brands [6], a critical asset in markets characterised by experience and credence attributes [13,17].

In the context of spirits, authenticity encompasses verification of product origin, brand integrity, composition, and production methods [18]. Counterfeiting specifically exploits information asymmetries involving deceptive practices where consumers are misled into purchasing falsely labelled or adulterated products [6,10,13].

Given that the global spirits market generates nearly half a trillion US dollars in annual revenue [3], and that illicit production and counterfeiting are often perceived as safer, more lucrative, and less severely punished crimes, the sector has become an especially attractive target for criminal activity [6].

In addition, the authentication of spirit and alcoholic beverages, and the detection of counterfeits is an arduous task and has required exhaustive method developments in the area of beverage analysis to date, to ensure that trace levels of adulterant constituents can be well separated from the dominant ethanol and water to allow for their characterisation and quantitation [2,19].

Traditionally, measures to combat counterfeiting have included physical security elements like tamper-evident packaging, chemical verification methods such as isotope analysis, and regulatory approaches including certifications and geographical indications [20,21,22]. However, these methods remain fragmented, costly, and sometimes are easily circumvented, resulting in high transaction costs including verification, compliance, monitoring, enforcement, and litigation [23,24]. The fragmented and globalized nature of spirits supply chains with numerous

intermediaries and varying regulatory environments amplifies information asymmetries and further complicates efforts to establish transparency as a mechanism for ensuring product authenticity [20,25].

Despite its economic importance and pronounced exposure to counterfeiting and illicit trade, the spirits sector remains comparatively under-researched in the economics and management literature on digital traceability and blockchain adoption, particularly when compared to wine and other agri-food products [26,27,28].

In response to authenticity and traceability challenges more broadly, a growing body of research has examined digital traceability and authentication technologies in agri-food and alcoholic beverage supply chains, with particular emphasis on blockchain-based solutions for improving transparency, provenance, and anti-counterfeiting capabilities [26,29]. Empirical studies on blockchain adoption in agri-food and wine supply chains document a wide range of potential benefits, including enhanced traceability, improved data integrity, and increased consumer trust, alongside persistent challenges related to implementation costs, scalability, and organisational readiness [27,28,29]. However, much of this literature remains technology-centric or adoption-focused and offers limited insight into the economic mechanisms through which blockchain affects information asymmetries and governance structures in high-value credence goods markets.

Against this background, blockchain technology (BCT) can be conceptualised not merely as a digital infrastructure, but as a potential governance mechanism. By providing decentralised, immutable, and transparent records of transactions across the supply chain, BCT reduces reliance on intermediaries and enables verifiable information at multiple stages of production and distribution [30,31,21]. These features align closely with Information Asymmetry Theory and Transaction Cost Theory, as blockchain may simultaneously strengthen authenticity signalling and screening while lowering verification, monitoring, and enforcement costs [32,33,34].

Taken together, these unresolved questions point to the need for an analytical framework that goes beyond adoption outcomes and explicitly examines how blockchain operates as an economic governance mechanism. In particular, empirical research integrating Information Asymmetry Theory and Transaction Cost Theory to analyse blockchain-enabled authenticity assurance in complex global spirits supply chains remains limited [35,36]. While BCT is widely regarded as enhancing information security and supply-chain resilience, contextual factors shaping its performance implications warrant closer investigation [21,34].

This paper addresses these gaps by investigating the adoption of blockchain for combating counterfeiting in the spirits industry. Anchored in Information Asymmetry Theory and Transaction Cost Theory, the study contributes to a more nuanced understanding of the institutional and economic conditions under which blockchain can reduce information asymmetry and transaction costs, thereby enhancing transparency and consumer trust. Specifically, the paper addresses the following research questions:

RQ1: How does BCT address information asymmetries in the spirits industry, particularly in relation to authenticity and counterfeiting?

RQ2: In what ways does blockchain reduce transaction costs for producers and other actors in the spirits value chain?

RQ3: What are the perceived benefits, challenges, and strategic motivations behind blockchain adoption among technology providers and spirits producers?

Methodologically, the study adopts a qualitative approach based on semi-structured interviews with key informants, including five authentication technology providers and three spirits producers. This design is appropriate given the exploratory nature of the research and its focus on complex, emerging governance dynamics. Interview data were analysed thematically using theory-driven coding informed by the two economic frameworks.

The remainder of the paper is structured as follows. Section 2 presents the theoretical framework. Section 3 details the research methodology. Section 4 reports the empirical findings, which are discussed in Section 5. Section 6 concludes with implications and directions for future research.

2. Theoretical Framework

While a growing body of literature has examined blockchain applications in agri-food and wine supply chains, this research has rarely been anchored explicitly in economic theories of information asymmetry and transaction costs, particularly in the context of the spirits sector. Existing studies tend to focus on adoption determinants, perceived benefits, or technological feasibility, offering limited insight into how blockchain alters market coordination and governance in high-value credence goods markets. Against this background, this section outlines the theoretical underpinnings of the study, drawing on Information Asymmetry Theory and

Transaction Cost Theory as complementary lenses for analysing authenticity, counterfeiting, and governance challenges in the spirits industry.

In the spirits sector, information asymmetries are a defining market characteristic. Spirits are not only experience goods whose quality can only be partly judged after consumption but often credence goods, as many consumers are unable to verify authenticity or quality even after tasting [17,21,37]. Such opacity creates strong incentives for misbehavior opportunistic behaviour on the producer and distributor sides [38,39] based on the uneven distribution of information leading to inefficiencies such as adverse selection and moral hazard [40,41]. The potential of information asymmetries is further exacerbated by the complex and global nature of spirits supply chains, ranging from the producers and their suppliers of raw materials for production or packaging, to off-trade (distributors, wholesalers, retailers) or on-trade actors (bars, pubs, hotels, restaurants), to the consumer, involving numerous intermediaries and prolonged ageing and storage periods, all of which heighten vulnerabilities to fraud [20,22]. Counterfeit spirits, which may use inferior or dangerous ingredients while mimicking premium brands, exploit these information gaps to deceive consumers.

Empirical studies in agri-food and wine markets confirm that traditional signalling mechanisms are increasingly insufficient in such complex and globalised supply chains. Systematic reviews and case-based analyses document widespread experimentation with blockchain-based traceability and authentication systems, particularly in wine, where provenance and quality signalling are central concerns [26,27,28]. While these studies provide valuable insights into adoption patterns and perceived benefits, they typically do not explicitly analyse how blockchain modifies the underlying information asymmetries that enable opportunistic behaviour, nor do they integrate these findings into a broader economic theory of market governance.

Effective mitigation of information asymmetries in credence goods markets often involves signalling and screening mechanisms [42,43,44]. Signalling refers to producers proactively communicating quality or authenticity to consumers through costly-to-imitate indicators such as brands, certifications or geographical indications strategically to differentiate genuine products from counterfeit alternatives [22,43].

From this perspective, blockchain-based systems can be interpreted as costly-to-imitate digital signals that embed verification directly into the product lifecycle, while simultaneously enabling

continuous screening by consumers, intermediaries, or regulators without relying solely on ex post analytical controls.

Conversely, screening allows consumers to assess these signals through third-party verification or analytical methods [20,37]. As information asymmetry is likely to increase when producers and consumers are farther apart and when more products from more distant regions become available, the need to for effective mitigation instruments is further amplified in the spirits sector due to its complex supply chain structure [45]. However, traditional signalling and screening mechanisms often entail substantial costs and remain vulnerable to fraud, underscoring the need for more robust solutions [23,37].

Transaction Cost Theory complements this perspective by emphasising the costs incurred in coordinating and safeguarding exchanges in environments characterised by uncertainty and limited trust [46,47,48]. Transaction costs include expenses related to searching for information, verifying claims, enforcing contracts, and resolving disputes.

In the spirits sector, transaction costs are exacerbated by the complex, globalized nature of supply chains as products pass through numerous intermediaries across diverse jurisdictions with varying regulatory standards. This complexity, combined with long ageing periods and fragmented oversight, increases vulnerabilities to fraud and elevates the costs of ensuring product authenticity [21,22].

Major spirits producers recognize these risks explicitly. For example, Diageo, one of the world's biggest spirits producers, highlights in its annual report Product Quality and Counterfeit as one of its main principal risks and lists numerous countermeasures it takes to address it, emphasizing their substantial cost: the measures include embedding anti-counterfeiting measures in packaging, running training and engagement programmes with law enforcement and customs officials across all high- and medium-risk markets, participating in industry initiatives to monitor and prevent counterfeiting activity, pursuing enforcement and prosecution, conducting training and awareness programmes with commercial teams and distributors across markets, managing glass collection and recycling programmes in medium- and high-risk markets to remove empty glass bottles from the counterfeit supply chain and prevent refilling, and running an online monitoring and take-down programme across high-risk e-commerce and social media platforms as well as directly engaging with these platforms to create awareness and stop counterfeit listings [24].

Furthermore, the enforcement costs must be considered as private sector and government institutions combat the distribution of illicit alcohol and counterfeiting: for example, the Alliance Against Counterfeit Spirits (AACS) states that since 2012, their activities have resulted in over 4 million bottles of counterfeit spirit being seized, the confiscation of over 3.6 million fake closures, as well as over twelve thousand anti-counterfeit enforcement actions stemming from their actions. Operation Opson, an operation conducted by Interpol together with Europol, involving 67 countries involved, as well as 22 private companies across its various stages since its start in 2011, only last year resulted in the seizure of approximately 850,000 liters of mostly alcoholic beverages [6,49]. Yet, the illicit nature of counterfeit alcohol inherently presents difficulties regarding access to reliable data [16,50] and despite the industry's efforts, the counterfeit situation affecting distilled spirits is always changing from category to category, region to region, and brand to brand [10], leading to calls for new technologies for effective traceability [51,13].

Adoption-focused studies of blockchain in agri-food and wine supply chains largely examine organisational readiness, perceived usefulness, and behavioural intentions [27,29]. While informative, this literature offers limited insight into how blockchain affects transaction costs once implemented, particularly with respect to verification, monitoring, and enforcement activities central to anti-counterfeiting strategies.

From a Transaction Cost Economics perspective, blockchain has been conceptualised as a governance mechanism capable of reducing coordination, monitoring, and enforcement costs by automating verification and reducing dependence on trusted intermediaries [46,35]. However, empirical evidence on realised cost reductions remains limited and context-dependent, especially in high-value credence goods markets such as spirits.

Blockchain potentially reduces transaction costs by providing reliable, tamper-proof, and transparent transaction records accessible to all stakeholders in real time [52,53]. Its decentralised architecture enhances transparency and trust by mitigating information asymmetry and reducing the scope for opportunistic behaviour [33,54]. Moreover, blockchain can reduce reliance on costly intermediaries traditionally employed for verification, thereby lowering monitoring and enforcement costs [31,55].

Beyond cost reduction, blockchain also serves as a strategic tool for cultivating consumer trust, particularly among premium-segment producers seeking to signal authenticity and exclusivity. Through digital certificates, NFT ownership, and traceable product histories, producers can

strengthen authenticity claims and enhance perceived value. This is especially relevant for Gen Z and Millennial consumers, for whom quality, sustainability, and exclusivity are key drivers [3]. Adoption in this context aligns with growing demand for transparency, traceability, and responsible consumption [56], outcomes that depend on blockchain's underlying role in reducing information asymmetry.

Taken together, Information Asymmetry Theory and Transaction Cost Theory provide a complementary framework for analysing blockchain adoption in the spirits industry. While the former explains why authenticity and counterfeiting problems persist in credence goods markets, the latter clarifies the costs associated with mitigating these problems through existing governance arrangements. By integrating these perspectives, this study conceptualises blockchain as a hybrid governance mechanism that simultaneously strengthens authenticity signalling and screening while reshaping the cost structure of verification, monitoring, and enforcement. This framework directly informs the empirical analysis and motivates the research questions guiding the study.

3. Methodology

3.1 Qualitative Exploratory Design

Given the nascent stage of BCT adoption in the spirits industry, a qualitative exploratory design was deemed appropriate for this study. This approach facilitates an in-depth understanding of complex phenomena, particularly when existing theoretical frameworks are limited or underdeveloped in specific contexts. Semi-structured interviews were selected as the primary data collection method to capture nuanced insights from key stakeholders involved in blockchain implementation for product authentication and anti-counterfeiting measures.

This design is appropriate for mechanism-oriented research aiming to explain how and why actors perceive blockchain as influencing authenticity assurance and governance costs, rather than to estimate population parameters. The interview approach enabled comparison across actor types (technology providers vs. producers), which is central to the study's theory-driven focus.

Secondary data sources such as company websites and brochures were used to support the interview process and findings.

3.2 Sample and Selection Criteria

The study employed purposive sampling to identify participants with direct experience in implementing or considering blockchain solutions within the spirits industry. The sample comprised eight participants: five representatives from technology firms specializing in authenticity and traceability solutions, and three executives from spirits production companies. Participants were selected using purposive, criterion-based sampling. Inclusion required (i) direct involvement in the design, deployment, or evaluation of blockchain-enabled (or blockchain-adjacent) authenticity/traceability solutions in spirits; and (ii) decision-relevant insight into adoption motivations, implementation constraints, or anti-counterfeiting strategy. To capture heterogeneity of adoption logics, the sample was structured to include both technology providers (solution-side perspective) and spirits producers (demand-side perspective), and to reflect variation in firm size and product positioning (premium/collectible vs. mainstream). The technology providers included companies specializing in NFC chip authentication, blockchain-based supply chain management, and hybrid public-private ledger solutions. The spirits producers ranged from a medium-sized European distillery focusing on premium products to globally operating groups experimenting with digital marketing tools and smaller artisanal distilleries emphasizing cost constraints. Technology providers were included if their firms had demonstrable engagement in developing or deploying authenticity/traceability solutions incorporating blockchain (public, private, or hybrid ledgers) and/or tokenisation (e.g., NFT-enabled certificates) for high-value products. Spirits producers were included if they (i) held responsibility for brand protection, quality assurance, digital innovation, or commercial strategy, and (ii) had experience with authenticity risks (e.g., counterfeiting, refilling, grey-market diversion) or were actively assessing related mitigation measures. This ensured that respondents could speak to both strategic motivation and operational feasibility. The sample size ($n=8$) reflects the exploratory and expert-oriented nature of the inquiry and the still-nascent diffusion of blockchain-based authentication in spirits. The aim was not statistical representativeness but analytical depth and comparison across actor types. Interviews were conducted until thematic saturation was reached at the level of core mechanisms relevant to the research questions (i.e., recurring patterns regarding signalling/screening logic, governance costs, implementation barriers, and strategic motivations).

3.3 Interview Guide

A semi-structured interview guide was developed to ensure consistency across interviews while allowing flexibility to probe emerging themes. Key topics included counterfeiting in the spirits sector, trust and transparency perceptions, cost implications, implementation challenges, specific blockchain use cases and applications, and consumer perceptions of blockchain-verified authenticity.

3.4 Data Analysis Approach

The qualitative data collected from interviews were analyzed using manual thematic analysis, guided by the theoretical frameworks of Information Asymmetry Theory and Transaction Cost Economics. Given the relatively small number of interviews ($n=8$), manual analysis was both feasible and allowed for an intensive, nuanced examination of the data.

The coding procedure was conducted in several structured phases. First, all interviews were digitally recorded with participant consent, anonymized, and transcribed verbatim. Next, transcripts were carefully read and re-read by the primary researcher to become thoroughly familiar with the content and to identify preliminary emerging themes, concepts, and patterns. Coding commenced by systematically highlighting key excerpts and assigning preliminary descriptive labels based on recurring phrases, explicit references to theory-informed categories, and significant insights relevant to the research questions. An initial coding structure was established deductively, drawing explicitly from predefined theoretical concepts (signalling, screening, transactions costs for verification or enforcement), while also allowing inductive codes to emerge organically to capture unexpected or novel insights.

Following initial coding, a comprehensive review of coded segments across all transcripts was conducted to refine, merge, or discard codes, ensuring internal coherence and external distinctiveness. This iterative refinement process facilitated the identification and grouping of related codes into clearly defined thematic clusters directly aligned with the study's theoretical framework and research questions.

Given resource constraints and the exploratory nature of this research, coding was performed by a single researcher. While the absence of multiple coders precludes traditional inter-rater reliability assessments, several measures were adopted to enhance coding reliability and validity. These included repeated coding sessions with intervals for reflection, meticulous documentation of

coding definitions and decisions, and peer debriefing sessions with an experienced qualitative researcher who provided critical feedback on the coherence, consistency, and theoretical alignment of coding categories. An audit trail documenting coding decisions and category definitions was maintained to enhance transparency and replicability of the analytic procedure

To strengthen construct validity, the study applied triangulation in line with case-study quality criteria [57]. Interview evidence was triangulated with secondary material (e.g., publicly available company documentation, product descriptions, technical brochures, and website information) to validate claims about use cases and implementation constraints. In addition, cross-actor triangulation was used by comparing producer and technology-provider accounts of the same categories of barriers and benefits, thereby reducing single-informant bias.

4. Findings

This chapter presents findings from interviews with five technology providers and three representatives of spirits producers. To preserve confidentiality, all participants and their affiliations are anonymized. The findings are structured along three theoretical lenses: blockchain as a tool for signalling and screening to mitigate information asymmetry, blockchain and transaction cost reduction, and strategic challenges of implementation.

4.1 Blockchain as a Tool for Signalling and Screening

All interviewed producers acknowledged the relevance of authenticity signalling, particularly for premium products. One medium-sized European distillery noted that while large-scale counterfeiting was not a direct issue, misrepresentation and grey-market sales were a concern, especially abroad. For them, digital certificates linked to each bottle or batch - potentially powered by blockchain - could offer reassurance about product origin and brand legitimacy.

Another producer with global reach, actively experimenting with digital tools, described blockchain as a key layer of trust, particularly when combined with tamper-evident NFC labels and smart packaging. The producer highlighted that NFT-based certificates were particularly valuable for collectible editions, where digital proof of ownership could be tied to access to exclusive events, customization options, or loyalty rewards. In contrast, a third, smaller-scale producer emphasized cost as the overriding concern in distillation and authentication. This

producer cited widespread cost-cutting as a major risk factor for authenticity, noting that authenticity solutions, no matter how secure, would be ignored unless cost-effective.

Technology providers focused heavily on physical-to-digital linkage. Some utilized encrypted NFC chips that detect tampering or Coravin-style puncturing, tied to unique digital identifiers. Others combined this with molecular markers, 360-degree bottle scans, or smart contracts. One platform noted the importance of each scan producing a new response, allowing the chip to signal tampering over time.

Another provider developed hybrid blockchain solutions, where public ledgers offered consumer-facing verification and private ledgers safeguarded sensitive business data. A third provider emphasized real-time supply chain data collection - temperature, humidity, and geolocation - using IoT devices that feed directly into the blockchain record. In all cases, the aim was to create a verifiable trail of authenticity and provenance that could be screened either by the consumer or upstream stakeholders.

Across both producers and providers, the question of whether consumers actually engage with these authentication tools remained open. All parties acknowledged that while younger and tech-savvy consumers in regions like Asia, the U.S., and South Korea were receptive, mainstream buyers showed limited awareness or understanding of blockchain. Producers favoured solutions where blockchain worked invisibly in the background. One provider suggested that scan rates on NFC chips were significantly higher than for QR codes, especially when tied to interactive storytelling or consumer rewards.

The producers emphasized the need for seamless integration: systems must not interfere with bottling processes or customer experience. One emphasized the potential for smart labels to evolve into two-way interfaces - tools for gathering CRM data, verifying geographic sales patterns, and launching push-notifications or loyalty rewards.

4.2 Blockchain and the Reduction of Transaction Costs

The cost-reducing potential of blockchain was widely recognized in principle but less commonly realized in practice. Larger producers cited early pilot programs that improved visibility, reduced inventory losses, and helped identify parallel import activity. For mid-sized producers, blockchain's promise lay in automating audits, simplifying compliance, and preventing grey-market diversion, though no direct savings had yet been measured. Using blockchain was also

reported as a foundation for traceability and engagement strategies tied to carbon tracking and ESG compliance, suggesting that long-term savings may emerge as sustainability metrics become monetized.

Secondary market engagement emerged as an important theme. One producer welcomed the idea of NFT-enabled bottle ownership to manage the resale of limited editions, provided resale platforms were transparent and legal. Smaller producers, by contrast, had not yet explored such resale dynamics, either due to resource constraints or market focus.

Technology providers described platforms that reduced verification overhead and enabled smart contract-driven resale. One system offered DeFi loans backed by physical bottles or barrels held in secure warehouses, eliminating traditional financing friction. Another provider's hybrid architecture automated compliance documentation, lowering costs related to trade certifications, bonded warehouse protocols, and inter-regional customs handling.

Real-time monitoring technologies also emerged as cost-saving enablers. IoT-tagged barrels or cases allowed producers to detect shipment anomalies, improper storage conditions, or unauthorized geographic diversions. Although few platforms offered quantified savings, most cited qualitative benefits including fewer disputes, faster recalls, and more informed production planning.

4.3 Implementation Challenges and Strategic Considerations

Barriers to adoption were numerous and varied. Producers cited cost, legal uncertainty (especially in EU markets), lack of blockchain fluency among internal teams, and fear of customer confusion. One producer remarked that their staff lacked the capacity to evaluate blockchain's potential, and that digital storytelling or traceability would only be attractive if seamlessly integrated into existing bottling and CRM processes.

Providers echoed these concerns. One reported that while producers often requested customized authentication systems, many lacked the digital infrastructure to deploy or maintain them. Another highlighted the challenge of designing systems that complied with local and international alcohol regulations while still enabling global verification and resale.

Notably, several interviewees emphasized that blockchain alone was not enough to earn consumer trust. Instead, trust stemmed from a blend of brand transparency, verifiable data, and consumer

interaction. One provider argued that their system should be seen not as "anti-counterfeiting tech" but as a marketing service that empowered consumers to make informed decisions. Interviewees diverged on whether blockchain would become a competitive edge or future standard. Larger producers with high-value SKUs viewed it as a key layer in their digital transformation. Smaller ones remained sceptical or passive, awaiting proven returns. Across the board, the most viable path to adoption appeared to be use-case-specific: blockchain as a backend enabler for limited editions, D2C engagement, or premium exports. Early adopters - especially in the spirits sector's collectible sub-markets - played a visible role in shaping adoption dynamics. One provider cited growing demand from tech-forward producers in Asia and Europe for solutions that combine authentication, logistics, and loyalty into a single, interoperable layer. In this sense, blockchain's future in the spirits sector may lie not in ubiquity, but in smart segmentation: high-value, high-risk, and high-engagement products leading the way.

5. Discussion

This chapter synthesizes the empirical findings through the lenses of signalling and screening to mitigate information asymmetry, and Transaction Cost Theory. It then discusses implications for producers, technology providers, and policymakers.

5.1 Theoretical Implications

5.1.1 Reinforcing and Challenging Economic Assumptions

The empirical findings affirm the centrality of information asymmetries in the spirits industry and validate the premise that Blockchain can function as a signalling mechanism. Interviews confirmed that traditional signals (e.g., packaging, labels, tax stamps) are insufficient, especially for credence goods like spirits. Producers and providers alike view Blockchain's immutability as a stronger signal of authenticity, particularly when tied to tamper-proof tags or molecular identifiers. This complements signalling theory by introducing a new class of costly-to-imitate digital signals that persist along the supply chain.

In this respect, the findings converge with prior studies in agri-food and wine supply chains that emphasise blockchain's role in strengthening authenticity signals and perceived product quality [58,26,59]. However, the present findings extend this literature by showing that signalling effects

are largely mediated through backend verification infrastructures rather than direct consumer-facing mechanisms.

This finding is consistent with marketing-oriented studies showing that blockchain-based traceability and authentication systems can function as credibility-enhancing signals that strengthen perceived product quality and brand value, particularly for premium food and beverage products [58,60].

Blockchain also enhances screening mechanisms, albeit unevenly. While advanced consumers and collectors in select regions use Blockchain-enabled interfaces to verify product authenticity, mainstream consumer uptake remains limited. This suggests that Blockchain currently performs a backend screening function more effectively than a consumer-facing one, challenging the assumption that screening mechanisms require active consumer behaviour.

This observation contrasts with adoption-oriented studies that implicitly assume active end-user engagement as a prerequisite for blockchain effectiveness, and instead suggests that much of the value creation occurs at the organisational and inter-firm level rather than at the point of consumer interaction. Related empirical work in the wine sector similarly reports that blockchain-enabled traceability enhances perceived transparency and consumer trust, while noting that trust is typically treated as an outcome variable rather than as an explicit economic mechanism [61].

Transaction Cost Theory is also supported. Producers cited Blockchain's potential to reduce fraud-related losses and streamline verification, compliance, and documentation - central elements of transaction costs in the spirit value chain. However, the reduction is most evident in large, integrated systems or high-value segments.

Analytical and game-theoretic models similarly predict that blockchain adoption can deter fraudulent behaviour and reshape incentives within supply chains under certain conditions [62]. Such models though rely on stylised assumptions and do not capture the organisational complexity, implementation costs, and heterogeneous actor motivations observed in real-world spirits value chains.

In many cases, cost-saving remains aspirational, revealing that Blockchain's effectiveness in reducing transaction costs is contingent on implementation scale and digital maturity.

This finding nuances Transaction Cost-based arguments in the blockchain literature, which often emphasise potential efficiency gains, by showing that realised transaction cost reductions depend

strongly on organisational scale, integration with existing systems, and the distribution of costs across actors [27,35].

5.1.2 Blockchain as a Hybrid Mechanism

A novel insight from the findings is the conceptualization of Blockchain as a hybrid mechanism that operates at the intersection of signalling mechanisms and transaction cost reduction. Platforms that integrate Blockchain with IoT, NFC, and AI serve dual purposes: they assure consumers of authenticity (signalling) and thereby build consumer trust, while improving internal efficiency and traceability (cost reduction). This duality expands the traditional boundaries of both theories, underscoring Blockchain's potential to unify disparate strategies for mitigating information asymmetries.

This hybrid conceptualisation advances existing literature by integrating insights that are typically treated separately. Prior studies tend to frame blockchain either as a signalling device emphasising transparency, trust, and perceived product quality from a marketing or consumer perspective [58,61], or as an efficiency-enhancing infrastructure focused on traceability, coordination, and governance within supply chains [26,27,35]. The present findings demonstrate that these functions are interdependent: signalling effects are reinforced by cost-reducing governance structures, while transaction cost reductions depend on the credibility of the signals generated.

This interpretation complements recent conceptual work in the wine sector that frames blockchain as playing a dual role in mediating credence attributes and supporting organisational capabilities, albeit from a strategic and dynamic capabilities perspective rather than through the lenses of Information Asymmetry and Transaction Cost Theory [36].

5.2 Industry Implications

Interviewees confirmed the value of trust added through BCT and its importance regarding key drivers like quality, sustainability, and exclusivity for younger consumer generations, aligning respective trends and consumer shifts. However, cost, especially for smaller producers, remains a primary constraint. As one interviewee put it, "even the best authentication system will be ignored if it's too expensive to implement." This suggests a segmented approach: producers of high-value SKUs can benefit from Blockchain traceability, while mainstream or price-sensitive segments require low-cost or indirect solutions. This segmentation logic aligns with prior adoption research

highlighting strong cost sensitivity and uneven value capture across firm types [34,52,55,29], while also helping to explain why broad-based adoption has remained limited despite generally positive expectations surrounding blockchain technology.

Another implication is that producers stand to gain not only in anti-counterfeiting but in CRM and loyalty management. Smart labels and NFC-based tags allow for two-way interaction, giving producers insight into who their consumers are and enabling direct engagement strategies. For example, one tech provider's use of real-time condition monitoring and smart contracts was already being tested for integrating loyalty programs and tasting experiences.

The findings emphasize the importance of user-centric design. Blockchain is still widely perceived as complex and opaque. Providers that offer seamless integration, backend simplicity, and intuitive user interfaces are more likely to succeed. A strong pattern emerged around the preference for systems that operate "invisibly" - providing assurance without requiring user expertise.

Education and strategic partnerships are also critical. Providers must not only deliver robust technical solutions but also invest in guiding producers through onboarding, compliance, and integration. Platforms that work with regulators, ERP vendors, and branding experts are better positioned to deliver holistic solutions.

Notably, some providers are beginning to move beyond authentication toward integrated value propositions: combining traceability, resale management, and consumer engagement. This evolution reflects the hybrid nature of Blockchain as both infrastructure and communication tool.

5.3 Policy and Regulation

From a public policy perspective, the findings raise important questions about the role of state institutions in safeguarding authenticity and traceability. As noted in the interviews and supported by scholars [6,16], enforcement is often fragmented, underfunded, or misaligned with the scale of the counterfeit problem. The suggestion that Blockchain could provide a more reliable registry of transactions resonates with calls for improved monitoring tools [10,51].

From an institutional perspective, recent research on PDO-based agri-food systems highlights blockchain and digitalisation as enabling technologies for governance, transparency, and regulatory coordination within complex quality regimes, particularly in the context of the twin digital and sustainability transition [63].

Yet, as some providers cautioned, Blockchain alone cannot replace legal enforcement or prevent grey-market trade without clear regulatory mandates. The combination of Blockchain with AI may help overcome resource constraints, allowing authorities to detect patterns or anomalies in supply chain data. However, this will require public-private collaboration, data-sharing agreements, and frameworks that ensure interoperability and data privacy. This observation is consistent with institutional perspectives that caution against treating digital technologies as substitutes for formal governance, and instead emphasise their role as complements to regulatory capacity and enforcement mechanisms [26,29].

Given the billions in lost tax revenues and the serious societal impacts arising from counterfeit spirits [6,16], regulatory institutions should take a proactive role in supporting blockchain integration.

Moreover, by registering transactional data immutably and in real time, Blockchain could support forensic tracing of illicit activity and strengthen legal evidence, addressing enforcement bottlenecks noted by Aylott and Aylott [10] and Spencer [16]. In this way, Blockchain solutions are not merely tools for private benefit but potential infrastructure for better governance.

Additionally, policy efforts should ensure that new blockchain-based authentication methodologies remain accessible, affordable, and legally admissible as evidence in prosecutions [6]. Considering the shifting consumer trends toward spirits among younger demographics [56], policymakers must also facilitate education and awareness campaigns around blockchain authentication technologies to maximize their societal and economic impact.

6. Conclusion

This study explored the role of BCT in addressing authenticity and counterfeiting challenges in the spirits industry. Anchored in the frameworks of Information Asymmetry and Transaction Cost Theory, the research examined how Blockchain-based solutions may improve transparency and efficiency across the value chain. The findings draw from in-depth interviews with five technology providers and three spirits producers, encompassing a range of perspectives from enterprise-scale innovators to artisanal distillers.

The problem of counterfeit and illicit spirits is vast, complex, and socially harmful. Traditional authentication methods remain vulnerable, fragmented, or cost-prohibitive, especially for smaller producers. Simultaneously, increasing product complexity and globalized distribution have

heightened the difficulty of ensuring traceability. Against this backdrop, Blockchain offers a decentralized and tamper-proof infrastructure capable of improving information flow, automating verification, and improving brand transparency to enhance consumer trust.

Empirically, the study found that Blockchain has significant potential as both a signalling mechanism and a transaction cost-reducing technology. Producers see value in digital certificates, NFC integrations, and NFT-enabled traceability, particularly for high-end and export-oriented products. Technology providers are evolving toward holistic platforms that not only prevent fraud but also enrich CRM, enable resale logistics, and foster loyalty. However, challenges persist. Barriers such as implementation cost, regulatory fragmentation, and limited consumer awareness currently hinder broad adoption, especially among smaller producers.

This research highlights the value of using economic theory to interrogate emerging technology applications in practice. Information Asymmetry Theory helped illuminate the shortcomings of traditional product signalling and the innovative potential of blockchain-enabled digital identifiers. Transaction Cost Theory framed the operational and compliance inefficiencies inherent in the existing system, demonstrating how blockchain may reduce verification and enforcement costs through automation and disintermediation.

Nevertheless, while Blockchain can support both consumer trust and organizational efficiency, its success will depend on ecosystem maturity and regulatory support. Technological robustness alone is insufficient without clear standards, user-friendly design, and strategic alignment among producers, platforms, and policymakers.

However, this study is subject to several limitations that should be considered when interpreting its findings. Methodologically, the qualitative and exploratory design, based on a small and purposive sample of eight interviews, does not aim at statistical representativeness but at analytical depth. While the inclusion of both technology providers and spirits producers allows for cross-actor comparison, the findings primarily reflect supply-side perspectives and do not capture consumer-level behaviour or regulatory decision-making directly. In addition, as blockchain adoption in the spirits sector remains at an early stage, several insights reflect expectations and strategic intentions rather than fully realised outcomes.

From a theoretical perspective, the study focuses on Information Asymmetry Theory and Transaction Cost Theory to interpret blockchain adoption. While these frameworks provide a strong lens for analysing authenticity and governance challenges, they do not exhaust all relevant

explanatory dimensions. Alternative perspectives, such as institutional theory, innovation diffusion, or behavioural approaches to trust and technology adoption, may offer complementary insights that are not fully addressed here.

Building on these limitations, future research should deepen this inquiry along several lines. First, consumer-side fieldwork is needed to understand how end users perceive and interact with Blockchain-verified spirits. Second, quantitative studies on cost savings and ROI are essential to substantiate the qualitative claims made by early adopters. Finally, further investigation is needed into the integration of Blockchain within regulatory systems - especially in the context of geographical indications, customs enforcement, and digital labelling laws. Such studies would help determine how Blockchain can transition from a premium niche application to a sector-wide standard supporting transparency, quality assurance, and governance in the global spirits market.

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