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Benefits and Drawbacks of Blockchain Technology for Traceability in Coffee Supply Chain

Christian Gómez * and Benoit Garbinato

Department of Information Systems, University of Lausanne, 1015 Lausanne, Switzerland; benoit.garbinato@unil.ch

* Correspondence: christian.gomez@unil.ch

Abstract

This research examines stakeholders' perspectives in Colombia and Switzerland on blockchain traceability systems in the coffee industry. Adopting the Unified Theory of Acceptance and Use of Technology (UTAUT) as an interpretive framework, the study analyzes these perceptions through the constructs of performance expectancy, effort expectancy, social influence, and facilitating conditions. Using a quantitative cross-sectional design with an exploratory scope, we survey 360 participants, comprising 60 coffee supply chain companies and 300 consumers. Results reveal that 78.3% of stakeholders consider traceability essential, yet only 46.7% are familiar with blockchain. Stakeholders identify three primary benefits: improved transparency (91.7%), fraud prevention (88.3%), and enhanced security (86.7%). However, significant barriers persist: high implementation costs (95%), limited expertise (91.7%), and lack of awareness (93.3%). Geographic differences emerge: Colombian stakeholders prioritize cost reduction and fraud prevention, while Swiss participants focus on data management and privacy protection. Among consumers, 62.7% express interest in provenance information, 56.7% are willing to pay for blockchain systems, and 59% are interested in tipping farmers. The study classifies benefits and drawbacks across nine dimensions, providing a comprehensive framework for understanding the multidimensional impacts of blockchain on the coffee supply chain.

Keywords: blockchain technology; traceability; coffee; supply chain; management information systems; supply chain management; UTAUT

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1. Introduction

The shift of supply chains to the digital world presents both advantages and risks for product traceability, transparency, and authenticity. In this regard, the coffee sector is a good example because coffee is one of the most consumed beverages in the world and one of the most traded commodities, with developing countries supplying more than 90% of the world's coffee [1]. The coffee supply chain includes production, transportation, storage, processing, export, import, roasting, and retail trade. Each of these stages may affect the final product [2].

The coffee industry faces various critical issues regarding supply chain management. Traditional logistics information systems are designed to receive and store orders without extending their functionality to support comprehensive traceability [3]. This deficiency becomes especially critical when poor supply chain oversight leads to problems such as incorrect product labeling, food safety issues, and a lack of information about the product's source and processing [4]. In addition, consumers are now more concerned about where

and how the food they consume is produced, leading to calls for sustainable production, product traceability, and fair compensation for farmers [4].

In response to these challenges, blockchain technology is seen as a potential solution for traceability in the food industry [5]. Blockchain is a decentralized, immutable method for recording transactions in the supply chain. The technology creates a permanent, shared record of transactions stored in a digital ledger, with each entry detailing the transactions between participants [6].

The use of blockchain technology in coffee supply chain management is an emerging trend that has started to capture people's interest in the last five years. Current developments range from conceptual studies to real-world cases, and most solutions are built on platforms such as Ethereum and Hyperledger [7,8]. Nevertheless, research has shown that the effective implementation of the model depends on both technological and organizational-level factors [9].

The integration of blockchain with other technologies, such as Internet of Things (IoT) sensors and artificial intelligence, has the potential to enhance the reliability of data collection and quality control [10]. However, there are still issues to address, including underdeveloped infrastructure in rural areas, data security concerns, and a lack of standards among supply chain actors [5].

Although previous research has investigated the application of blockchain technology in the coffee supply chain, we identify three persistent knowledge gaps through a search of the relevant literature. First, from a theoretical perspective, existing Unified Theory of Acceptance and Use of Technology (UTAUT) blockchain adoption studies in agri-food supply chains typically test causal relationships between UTAUT constructs and adoption intention within a single stakeholder group or geographic context [11–13]. However, none of these studies use UTAUT as an interpretive framework to analyze the interplay between perceived benefits and drawbacks across a wider spectrum of supply chain actors (from farmers to consumers) and across contrasting geographic contexts (producing vs. consuming countries). Second, from an empirical standpoint, the existing literature predominantly addresses either technical implementation aspects, such as smart contract design and prototype development [7,8,10,14], or examines single stakeholder perspectives, such as coffee producers [4] or consumers [15,16]. There is a lack of empirical evidence on how different stakeholders in the coffee supply chain perceive the benefits and drawbacks of blockchain for traceability, and how these perceptions diverge between a producing region (Colombia) and a consuming region (Switzerland). Third, from a practical perspective, no prior study in the current literature classifies the perceived benefits and drawbacks of blockchain technology across multiple operational and business dimensions, offering a multidimensional framework that practitioners can use to guide adoption decisions tailored to their specific operational priorities and geographic context.

In this context, this study aims to answer the following research questions (RQ):

- RQ1: What is the perception of coffee industry stakeholders about traceability?
- RQ2: What is the perception of coffee industry stakeholders about using blockchain technology for traceability?
- RQ3: What benefits and drawbacks are expected by coffee industry stakeholders using blockchain technology for traceability?
- RQ4: How can all these benefits and drawbacks be classified according to the operational and business dimensions? E.g., Time–Costs–Processes–Staff–Consumer Satisfaction–Sales–Market Share.

To provide a theoretically grounded interpretation of stakeholder perceptions, this research utilizes the Unified Theory of Acceptance and Use of Technology (UTAUT) as an interpretive framework. UTAUT proposes four core constructs: performance expectancy,

effort expectancy, social influence, and facilitating conditions, which determine technology adoption behavior [17–19]. By analyzing the identified benefits and drawbacks through these constructs, the analysis presents a structured understanding of the factors that promote or hinder blockchain adoption in the coffee supply chain.

This article offers three distinct contributions. First, it advances the theoretical application of UTAUT by employing it as an interpretive framework to analyze perceived benefits and drawbacks across the supply chain, between producing and consuming country contexts, rather than testing causal hypotheses within a single stakeholder group. This approach reveals that geographic context serves as a prominent moderating variable, producing significant differences across nearly all UTAUT constructs, a finding that single-context studies cannot identify. Second, it provides novel empirical evidence from 360 participants spanning nine stakeholder clusters in Colombia and Switzerland. Third, it delivers practical value by proposing a nine-dimensional classification framework for blockchain benefits and drawbacks that practitioners, technology providers, and policymakers can use to design context-specific implementation strategies aligned with their operational priorities and resource constraints.

The paper proceeds to Section 2, which specifies background on blockchain technology in agri-food supply chains, with an emphasis on the coffee value chain, and establishes the theoretical framework employed in the research. Section 3 describes the methodology, including research design, data collection, and analysis procedures. Section 4 presents the results of the stakeholder survey and analysis. Section 5 discusses the findings in light of the review of related literature, interprets the results through the lens of the UTAUT framework, and outlines practical implications, limitations, and recommendations for future research. Finally, Section 6 concludes the paper.

2. Background

This section explains the principles of blockchain technology and its applications in supply chain management for agri-food systems, with specific examples from the coffee industry. This background section establishes the theoretical framework for understanding blockchain solutions for traceability in complex agricultural supply chains.

2.1. Blockchain Technology Fundamentals

The distributed ledger system known as blockchain utilizes cryptographic hashes, digital signatures, and peer-to-peer networks to establish an unalterable record of transactions [20]. Data stored in blockchain technology exists as linked time-stamped blocks that contain digital transaction records between network participants [2]. The decentralized design of blockchain technology renders centralized authorities unnecessary, as robust consensus algorithms protect data integrity [21].

Blockchain technology suits supply chain operations because it offers immutability, transparency, decentralization, and IoT integration capabilities [8,10]. These features address key requirements for supply chain traceability, including data transparency, data security, data reliability, process efficiency, and system integration [20].

2.2. Blockchain Applications in Supply Chain Management

The supply chain management industry focuses on blockchain because some studies suggest that the technology could reduce costs by 15–20% across supply chain operations [1,3,13,21]. The technology demonstrates versatility across various implementation tests, proving its effectiveness in solving traceability problems [2,3,5,7,8,10,14,21]. For example, the agricultural sector uses blockchain for various commodities: organic food [22], olive oil [23], cocoa [24], fruits and vegetables [25], soybeans [26], milk [27], and meat [28].

These applications typically focus on creating end-to-end traceability systems to establish visibility across product movements while preserving data security and transparency.

The implementation of blockchain-based traceability systems proves their practical effectiveness through commercial use. The IBM Food Trust platform uses Hyperledger Fabric to create permissioned, permanent, shared data records for food supply chain participants [29]. Walmart, Carrefour, and Amazon develop blockchain systems to ensure the traceability of pork, poultry, beef, and multiple agricultural products [30].

2.3. Blockchain Technology in the Coffee Supply Chains

Blockchain technology proves highly suitable for the coffee industry because it addresses the complex global supply chain networks and requirements for origin verification. Various stages of coffee supply chain blockchain solutions exist, ranging from conceptual designs to prototype implementations that use Ethereum or Hyperledger platforms [31].

The current blockchain systems in coffee supply chains primarily employ Ethereum-based solutions that manage user registration, order management, supply chain tracking, and product verification through Solidity smart contracts [7]. Integrating QR codes in these systems allows consumers to access traceability information.

The implementation of Hyperledger Fabric focuses on building permissioned networks that achieve transparency by applying necessary privacy restrictions for business applications [32]. These solutions use multiple channels to provide supply chain visibility for authorized participants while preserving confidentiality.

Blockchain systems become more powerful when integrated with additional technological elements. IoT sensors automatically collect data about environmental conditions, quality parameters, and location information [10]. Machine learning algorithms enable quality assessment and predictive analytics, which are supported by mobile applications that offer user-friendly interfaces for stakeholders and consumers [14].

The coffee supply chain industry demonstrates blockchain capabilities through various significant implementations. The Coffee Board of India has created a blockchain system that enables coffee farmers to connect directly with buyers and tracks coffee beans from farms to consumers' cups. This implementation system enables the verification of geographical indicators and supports fair value distribution among supply chain stakeholders [33]. Starbucks, for instance, implements blockchain technology across its supply chain operations, enhancing product transparency and maintaining quality standards [34]. Similarly, Lavazza applies blockchain technology to Brazilian coffee farms, using sensors to collect environmental data, production records, and processing information, all recorded on the blockchain to ensure complete traceability from farm to consumer [35].

2.4. Benefits and Challenges of Blockchain Implementation

2.4.1. Documented Benefits

Research shows that implementing blockchain in coffee supply chains offers multiple essential advantages [8]. Applying this technology leads to greater trust among supply chain participants, reduced counterfeiting and fraud, fair trade practices, and improved traceability and transparency [9]. Blockchain technology enables real-time tracking of coffee from farmers to consumers, allowing access to detailed information on origin, processing methods, and quality parameters [6].

The technology enables consumers to make better purchasing decisions by accessing verified information about coffee provenance, farming practices, and fair-trade certifications [15]. It also permits sustainability verification of environmental impact and social compliance standards [36].

2.4.2. Documented Challenges

The implementation of blockchain technology in coffee supply chains faces significant challenges despite its potential benefits [8]. The technical infrastructure limitations, especially in growing areas, are a primary barrier to blockchain adoption [4]. Many farmers lack access to reliable internet connections and the digital literacy required to participate in the system [13].

Once data is stored on the blockchain, its integrity remains secure, but the system cannot prevent incorrect initial entries [6]. Maintaining traceability becomes more complex because coffee supply chains frequently combine products from various origins [37]. The high implementation costs also pose an obstacle for small-scale producers, yet the main supply chain benefits accrue to other participants [4]. The implementation process becomes more difficult due to regulatory uncertainties and the lack of industry standards [38].

2.5. Theoretical Framework: The Unified Theory of Acceptance and Use of Technology (UTAUT)

Understanding why stakeholders adopt or resist new technologies is essential for evaluating the potential of blockchain-based traceability in the coffee supply chain. The Unified Theory of Acceptance and Use of Technology (UTAUT), developed by Venkatesh et al. [17], provides a comprehensive framework for analyzing technology adoption behavior. This study uses UTAUT only as an interpretive lens for its findings.

UTAUT synthesizes eight prominent models of technology acceptance: the Theory of Reasoned Action (TRA), the Technology Acceptance Model (TAM), the Motivational Model (MM), the Theory of Planned Behavior (TPB), a combined TAM-TPB model, the Model of PC Utilization (MPCU), the Innovation Diffusion Theory (IDT), and the Social Cognitive Theory (SCT). By integrating the core elements of these models, UTAUT achieves an adjusted R^2 of 70 percent in explaining usage intention, a substantial improvement over any of the individual models, which explained between 17 and 53 percent of variance [17].

UTAUT posits four core constructs that determine behavioral intention and use behavior: performance expectancy (PE) refers to the degree to which an individual believes that using the system will help him or her to attain gains in job performance; it is consistently the strongest predictor of intention across settings; effort expectancy (EE) refers to the degree of ease associated with using the system and is most salient in the early stages of adoption; social influence (SI) refers to the degree to which an individual perceives that important others believe he or she should use the new system; facilitating conditions (FC) refers to the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system. These four constructs are moderated by gender, age, experience, and voluntariness of use, which shape the strength and direction of the relationships between the constructs and behavioral intention [17]. Venkatesh et al. [18] extend UTAUT to UTAUT2 by incorporating hedonic motivation, price value, and habit for consumer contexts, while Venkatesh et al. [19] further propose that conceptualizing UTAUT within specific contexts can expand and improve it. Since its publication, UTAUT has been widely applied in technology adoption research. Williams et al. [39] review 174 UTAUT-related articles and confirm that performance expectancy and behavioral intention consistently qualify as the best predictors.

In the domain of blockchain technology adoption in agri-food supply chains, UTAUT has emerged as a prominent theoretical framework. Surarityothin et al. [11] apply UTAUT to blockchain adoption among coffee supply chain stakeholders in Thailand, finding that performance expectancy is the strongest determinant of adoption intention, with age as a significant moderating variable. Kramer et al. [13] combine UTAUT with the Theory of Planned Behavior to study blockchain adoption in agri-food supply chains, confirming the relevance of performance expectancy, effort expectancy, and facilitating conditions.

Bentivoglio et al. [12] employ an extended UTAUT model with trust to examine blockchain adoption among Italian winemakers, finding that only performance expectancy and trust significantly predict behavioral intention.

2.6. Research Gaps and Opportunities

While existing literature provides valuable insights into blockchain applications in coffee supply chains, this research identifies three specific research gaps that it aims to address. First, a *theoretical gap* exists regarding the use of UTAUT in blockchain research on traceability. Existing UTAUT-based studies in agri-food contexts employ the framework to test causal hypotheses about adoption intention. For instance, Surarityothin et al. [11] find performance expectancy as the strongest determinant of adoption in Thailand, Bentivoglio et al. [12] report that only performance expectancy and trust predict intention among Italian winemakers, and Kramer et al. [13] confirm the relevance of performance expectancy, effort expectancy, and facilitating conditions. However, current literature focuses on single stakeholder groups within single geographic settings, without applying UTAUT as an interpretive lens to examine how the four core constructs manifest simultaneously across multiple stakeholder roles and contrasting geographic contexts, thereby bypassing adoption dynamics that single-context studies cannot capture.

Second, an empirical gap persists in the scope and breadth of stakeholder coverage. As a recent systematic literature review covering 39 studies on blockchain for coffee traceability confirms [8], the majority of the existing literature focuses on technical implementations (prototypes and frameworks) rather than comprehensive empirical analyses of stakeholder perceptions. Studies that do examine perceptions typically address a single actor group (e.g., Singh et al. [4] study coffee producers, Dionysis et al. [15] examine consumer purchasing intentions, and Crowley [16] investigates consumer willingness to pay) without integrating perspectives across the supply chain from farm to cup. Furthermore, most empirical studies are situated in a single geographic context (e.g., Thailand [11], Italy [12], Peru [40], Ethiopia [41]), thereby limiting understanding of how contextual factors shape perceptions of benefits and drawbacks. This study addresses this gap by surveying 360 participants across nine stakeholder clusters in two contrasting regions: a producing country (Colombia) and a consuming country (Switzerland).

Third, a practical gap exists between research findings and actionable guidance. Prior studies identify benefits and drawbacks of blockchain in general terms [42,43] but do not classify them by the specific operational and business dimensions that practitioners use in decision-making. The present work proposes a novel nine-dimensional classification framework (time, cost, process, staff, consumer satisfaction, sales, market share, transparency and information, and cooperation and collaboration) that organizes stakeholder-identified benefits and drawbacks into categories directly relevant to managerial assessment and investment planning.

Moreover, integrating multiple technologies (blockchain, IoT, AI) offers additional research opportunities to develop more comprehensive and effective traceability solutions [44]. Likewise, there is a need to address standardization requirements, regulatory frameworks, and sustainable business models for blockchain-based coffee supply chain management [8]. Therefore, our study aligns with the current research landscape by exploring the perspectives of coffee stakeholders to understand their needs, benefits, and drawbacks of implementing blockchain for traceability in the coffee industry.

3. Methodology

This section describes the methodology that we follow in the research. The current study uses a quantitative approach with an observational design and an exploratory

scope, as it examines stakeholder perceptions regarding a technology (blockchain) that remains in early adoption stages within the coffee supply chain. Rather than testing causal hypotheses about adoption behavior, this research seeks to identify and describe perceptual patterns across stakeholder groups and geographic contexts, generating insights that can inform future confirmatory research. The study variables are measured cross-sectionally because a time cut is made at the time of data collection, corresponding to the study's execution period.

3.1. Population and Sample

The selection of these two specific regions is purposive rather than random. Huila is selected because it is one of the leading coffee-producing departments in Colombia, contributing significantly to the country's coffee output [45], and it provides access to all upstream supply chain actors (farmers, local traders, millers, transporters, and exporters). Vaud is selected because Switzerland is one of the largest coffee importers globally, hosting major coffee companies such as Nespresso [46], and this canton provides access to downstream supply chain actors (importers, roasters, distributors, and consumers). This purposive geographic selection enables comparison across a producing country and a consuming country context, but it does not permit generalization to all coffee-producing or consuming regions.

Figure 1 shows different stages and principal stakeholders in the coffee supply chain: farmers, local traders, millers, transporters, exporters, importers, roasters, distributors, and consumers. For our study, we consider the stakeholders in the Department of Huila, Colombia, from farmers to exporters (left side of Figure 1), and the stakeholders in the Canton of Vaud, Switzerland, from importers to consumers (right side of Figure 1).

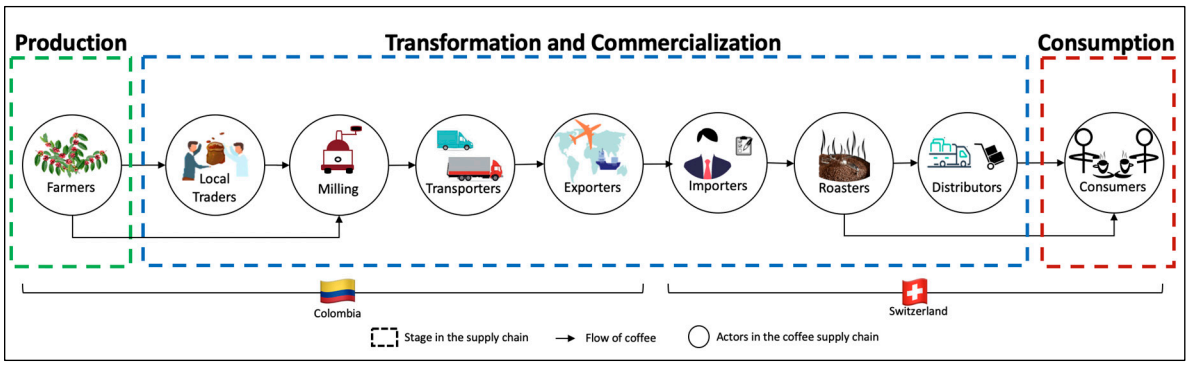


Figure 1. Stages and main stakeholders in the international coffee supply chain.

The sample for this exploratory study is 360 stakeholders in the coffee supply chain. These 360 stakeholders are 60 companies (farmers, local traders, millers, transporters, exporters, importers, roasters, and distributors) and 300 consumers. The company sample size follows the recommendations of Marshall et al. [47], who review sampling practices in Information Systems research, and find that studies with structured data collection instruments and clearly defined populations can achieve data saturation with relatively small samples per subgroup, particularly when the research objective is to capture perceptual patterns rather than to estimate population parameters. Accordingly, we sample 30 company stakeholders per location (Colombia and Switzerland), obtaining 60 companies in total. For the consumer sample, we surveyed 300 participants in Vaud, Switzerland.

We apply non-probabilistic convenience sampling, as proposed by Taherdoost [48], because, to achieve the study's objective, we need stakeholders who meet the selection criteria and voluntarily want to participate. Additionally, to ensure the participation

of diverse stakeholders in the coffee supply chain, we use cluster sampling, with each stakeholder in the supply chain as a cluster. Thus, we get 9 clusters in total (one for each stakeholder in Figure 1). There are 5 clusters in Huila, Colombia (left side of Figure 1), and 4 clusters in Vaud, Switzerland (right side of Figure 1).

Furthermore, to ensure the participation of the 5 stakeholder clusters in the Department of Huila, we divide the sample size for this location, which is 30, among the 5 clusters, resulting in 6 participants per cluster. Similarly, in the Canton of Vaud, we divide the sample of 30 at this location into 3 clusters, getting 10 participants per cluster. The fourth cluster in Switzerland corresponds to consumers; we sample 300 participants for this cluster.

The resulting company subgroup sizes (6 per Colombian cluster, 10 per Swiss cluster) are consistent with sample sizes reported in comparable blockchain adoption and UTAUT studies in agri-food contexts. For instance, Tharatipyakul et al. [6] conduct in-depth interviews with 10 participants (5 producers and 5 consumers) and surveys to 350 stakeholders in their study of blockchain-based traceability in the Thai coffee supply chain; Bentivoglio et al. [12] survey 114 Italian wine producers using an extended UTAUT model; Singh et al. [4] study 31 coffee producers in a blockchain pilot project; Crowley [16] examines consumer willingness to pay with a survey sample of 113 participants. These precedents indicate that our total sample of 300 consumers and 60 company stakeholders across eight clusters, while modest in per-cluster size, is within the range of comparable studies in this emerging field.

We acknowledge that the non-probabilistic convenience sampling approach and the small per-cluster subgroup sizes limit the statistical power for fine-grained inferential comparisons at the individual cluster level and restrict generalizability to other coffee-producing or consuming regions. The findings from the company survey should therefore be interpreted as exploratory insights into stakeholder perception patterns rather than as statistically representative estimates of the broader coffee industry population. The consumer sample (n = 300) provides greater statistical power but remains limited to a single geographic context (Canton of Vaud, Switzerland).

3.2. Selection Criteria

The selection criteria embrace inclusion and exclusion criteria. They are the same for both application locations of the study, i.e., Huila and Vaud. We include companies that play a specific role in the coffee supply chain (stakeholders in Figure 1) and have been in the market for at least 1 year. We exclude companies that combine coffee with other products without separate metrics. We include consumers who drink coffee and who agree to participate freely and voluntarily in the research.

3.3. Instruments

We developed two surveys to collect data from stakeholders in the coffee supply chain. The first instrument is for companies, from farmers to distributors (Figure 1), and the second instrument is only for consumers.

The first survey is titled “Benefits and Drawbacks of Blockchain Technology for Traceability in the Coffee Supply Chain”. It allows us to measure demographic variables and variables related to the perception of coffee stakeholders about traceability, blockchain technology, its benefits and drawbacks. This survey is structured into three sections: First, “Participant companies and perception about traceability”, with nine questions; second, “Perception about blockchain technology”, with eight questions; third, “Potential benefits and drawbacks”, with six questions. This gives us a total of 23 questions, with single and multi-select options. Supplementary Materials show the first instrument.

The second survey is titled "Consumers' Perception". It lets us measure demographic variables and variables related to coffee consumers' perceptions of traceability and blockchain technology, as well as their willingness to pay and tip for trusted information about the provenance and journey of coffee. This survey has 10 questions in total, with single-select and multi-select formats. Supplementary Materials present the second instrument.

To design these instruments, we submit two questionnaires to assess face and content validity, comprising 26 questions for the first and 14 for the second. Following the recommendations of Escobar and Cuervo [49], we begin by specifying the objective of validating the face and content of the designed questionnaires, and then select expert evaluators, who are informed about the instrument's objective, dimensions, and evaluation mechanism.

We select the judges according to the criteria by Skjong and Wentworth [50], considering that the experts have research experience, with projects and publications on coffee and/or technology, as well as availability and motivation to participate. Thus, we get four experts who are not authors of this paper. Once we obtain the assessment, we assess face validity using Cohen's kappa coefficient [51] as a measure of inter-rater reliability, Aiken's V [52], and content validity using Lawshe's method [53]. We present the details of the face and content validity hereafter, which allow us to obtain the final instruments for collecting data from companies and consumers.

3.3.1. Face Validity

Face validity is measured by calculating Cohen's kappa coefficient and Aiken's V coefficient through the evaluation of four experts, who are asked to rate each item on a scale of 0 when it is not fulfilled and 1 when it is fulfilled. We start calculating Cohen's kappa coefficient on the first three criteria: clarity, accuracy, and comprehension. We find a simple concordance index of 0.91 for the first instrument, interpreted as near-perfect (Kappa > 0.8), and 0.85 for the second instrument. We present the detailed description of Cohen's kappa coefficient for each question of the two instruments in Supplementary Materials.

Subsequently, we analyze the coherence, relevance, and sufficiency of the instruments using Aiken's V coefficient, which is considered acceptable when it exceeds 0.8 [52]. Supplementary Materials show the results per question of the two instruments. Seven items obtained a low Aiken's V coefficient (<0.8): three items (4, 12, and 13) in the first instrument, for companies, and four items (3, 4, 9, and 10) in the second instrument, for consumers. The judges suggest eliminating these seven items.

For the entire first instrument, we obtain an Aiken's V coefficient of "0.87" with a 95% Confidence Interval (CI) (0.62–0.95), which is interpreted as adequate agreement between judges and does not require adjustment. However, after eliminating the three items rated by the experts as not relevant, the instrument with 23 questions obtains an Aiken's V coefficient of 0.93, with a 95% CI of 0.67–0.98, interpreted as excellent agreement.

For the whole second instrument, we achieve an Aiken's V coefficient of "0.85" with a 95% CI of 0.68–1.01, which means adequate agreement among judges (no adjustment required). Once the four items not relevant (3,4,9, and 10) are eliminated, Aiken's V coefficient of 10 items is 0.91, with a 95% CI of 0.77–1.05, meaning excellent agreement.

3.3.2. Content Validity

Content validity is determined by consensus among four experts, who calculate the Content Validity Ratio (CVR) using Lawshe's method, in which the experts rate each item on a scale of 0 when it is not fulfilled and 1 when it is fulfilled, assigning this rating to essential, useful but not essential, or not essential. According to the recommendations, we consider a value of 0.75 or higher as statistically valid [53].

After applying this measure to the first instrument, we obtain a CVR of 0.85. However, three items are rated by the experts as non-essential (Items 4, 12, and 13), which correspond to the same three items rated as not very relevant in the face validity. Therefore, after eliminating these three items, we recalculate the CVR for the entire instrument and find it to be 0.96, indicating adequate content validity. Supplementary Materials list the CVR results per item.

In the second instrument, the initial CVR was 0.7. However, after eliminating the four items suggested by the experts (3, 4, 9, and 10), the instrument showed a CVR of 0.95, indicating good agreement among the judges regarding the items' relevance. We present the full item-level results for the CVR in Supplementary Materials.

The items removed from both instruments were either similar to others already included or of little relevance to the phenomenon under study; therefore, their removal did not affect construct coverage. On the contrary, removing them resulted in improved face and content validity for the complete instruments.

3.4. Data Collection

The unit of analysis and information is the stakeholders in the coffee supply chain to whom we apply the instruments. Data collection is conducted through two surveys that include closed-ended questions with response options. We obtained ethics approval from the University of Lausanne (UNIL) to conduct the project research. We obtained informed consent from participants, in which we described the study, participation conditions, no remuneration, confidentiality, data processing, and their rights under data protection procedures to stop participating, access their information, or have it removed. We do not collect any personal, sensitive, or contact information from participants, ensuring complete anonymity and confidentiality of responses.

We conduct both instruments via the Qualtrics platform, which is endorsed by the University of Lausanne (UNIL) for research surveys. Thus, we initially contact coffee companies from the list of companies in the coffee sector, which we obtain from the Chamber of Commerce of Huila, Colombia, and a coffee association in Switzerland. We use the Qualtrics online survey platform to survey 300 coffee consumers in Switzerland.

We contact companies by phone and email, inviting them to participate in the study and, if they wish, scheduling a survey appointment. For those who prefer to respond by phone, we request verbal consent and administer the survey in a targeted manner. And for the companies that prefer it by email, we send them the link to the consent form for their approval and the survey to be filled in.

3.5. Data Processing and Analysis

The data analysis is conducted in accordance with the research questions and is presented both in general for all participants and by stakeholder cluster. We use descriptive and inferential statistics to analyze the information. Categorical or qualitative variables are described using absolute and relative frequencies. We employ a comparative analysis of stakeholders using non-parametric statistics, with Pearson's chi-squared test when expected frequencies in each cell are $\geq$5; otherwise, we use Fisher's exact test. For the questions with more than two response options, we use the likelihood ratio. Also, we use the binomial test to compare data from a sample with two response options, and for more than two response options, we use the nonparametric asymptotic chi-square test. All these tests are considered significant at $p \leq 0.05$.

We handle the multi-response items by analyzing each response option and dichotomizing them: "Yes" when selected, "No" when not selected. We then present the absolute and relative frequencies of each multi-response item for every stakeholder. Next,

the frequencies for each item were summed to determine the total number of responses in each geographic context (Colombia and Switzerland), and the results were analyzed in a 2 × 2 table to compare them, obtaining their differences (p-value). The effect size is estimated using the Odds Ratio (OR) test with 95% confidence intervals (CI) for dichotomous variables (considering OR ≤ 1 as no association, 1.1–2.4 as low association, 2.5–3.9 as moderate association, and $\geq$4 as strong association). For non-dichotomous variables, the effect size is calculated using Cramer's V via bootstrapping with 95% confidence intervals (considering V: between 0 and 0.09 as no association, 0.10 and 0.30 as low association, 0.31 and 0.50 as moderate association, and >0.50 as strong association). We calculate the effect size only for variables that showed a statistically significant difference ($p < 0.05$). We perform all the analyses using SPSS software version 29.

3.6. Declaration on the Use of Generative Artificial Intelligence (GenAI)

During the preparation of this manuscript, generative AI tools were used for citing literature, collecting online surveys, improving the readability of figures, statistical calculations, and refining the English language. After using these tools, the authors reviewed and edited the outputs and take full responsibility for the content of this publication.

4. Results

This section presents the results we obtained by applying both instruments. We surveyed 360 stakeholders in the coffee supply chain, which includes 60 companies and 300 consumers. These 60 companies comprise 30 in Colombia (farmers, local traders, millers, transporters, and exporters) and 30 in Switzerland (importers, roasters, and distributors). The 300 consumers are from Switzerland. We apply the first instrument to the companies and the second instrument to consumers. We collect data through online surveys on the Qualtrics platform. We present the findings hereafter.

4.1. Results for Companies

This section presents the findings from the survey of 60 coffee supply chain stakeholders across Colombia (Department of Huila) and Switzerland (Canton of Vaud). We address research questions regarding stakeholders' perceptions of traceability, blockchain technology adoption, and the anticipated benefits and drawbacks of implementing blockchain for coffee traceability. The results are structured according to the three main sections of the survey: participant characteristics and perceptions of traceability (RQ1), perceptions of blockchain technology (RQ2), and potential benefits and drawbacks (RQ3 and RQ4).

4.1.1. Participant Characteristics and Perception About Traceability—RQ1

The study sample comprises 60 companies representing eight different stakeholder clusters across the coffee supply chain (n = 60). Supplementary Materials present the demographic characteristics and traceability perceptions of participants (RQ1) distributed across Colombian stakeholders (farmers n = 6, local traders n = 6, millers n = 6, transporters n = 6, and exporters n = 6; total n = 30) and Swiss stakeholders (importers n = 10, roasters n = 10, and distributors n = 10; total n = 30). We describe these insights hereafter.

- Demographic Characteristics

Professional experience presents significant differences between Colombian and Swiss stakeholders (p = 0.043). Among Colombian participants, 46.7% report less than three years of experience, 23.3% have between three and six years, and 30% possess more than six years of experience in their respective roles. In contrast, Swiss stakeholders demonstrate greater experience: 40% report less than three years, 26.7% between three and six years, and 33.3% more than six years.

The analysis reveals highly significant differences ($p < 0.001$) in the diversity of coffee provenances handled by stakeholders. All Colombian farmers work with coffee from a single provenance, while other Colombian stakeholders demonstrate increasing diversity, working with 1–3 provenances; most exporters work with coffee from more than three provenances. Among Swiss stakeholders, importers and distributors show the highest diversity, handling more than three provenances.

Regarding monthly coffee volumes, we identify that 51.7% of surveyed stakeholders handle less than 1000 kilos per month. The comparison between Colombian and Swiss stakeholders in terms of volume handled shows no significant difference ($p = 0.068$).

- Current Trust Levels in Information Sharing

Trust in supply chain information sharing varies significantly between the two sample geographic contexts studied ($p = 0.015$). While 63.3% of all participants rate current trust as moderate, the distribution around this midpoint diverges: Colombian stakeholders skew toward lower trust (41.7% rating trust as low or moderate), whereas Swiss stakeholders lean positive (43.3% rating trust as moderate or high). This asymmetry may reflect structural differences in supply chain organization.

- Importance of Traceability

The perceived importance of traceability illustrates highly significant differences between groups ($p < 0.001$). Among surveyed stakeholders, 78.3% ($n = 47$) consider traceability either very important or essential in the coffee supply chain. Swiss stakeholders demonstrate greater recognition of the importance of traceability, with 50% ($n = 15$) rating it as essential, compared with 20% ($n = 6$) among Colombian stakeholders. Also, 16.7% ($n = 5$) of Colombian stakeholders consider traceability as somewhat important, while no Swiss stakeholders share this perception. All participants recognize at least some importance of traceability, as no one rates it as unimportant. Figure 2 shows these results.

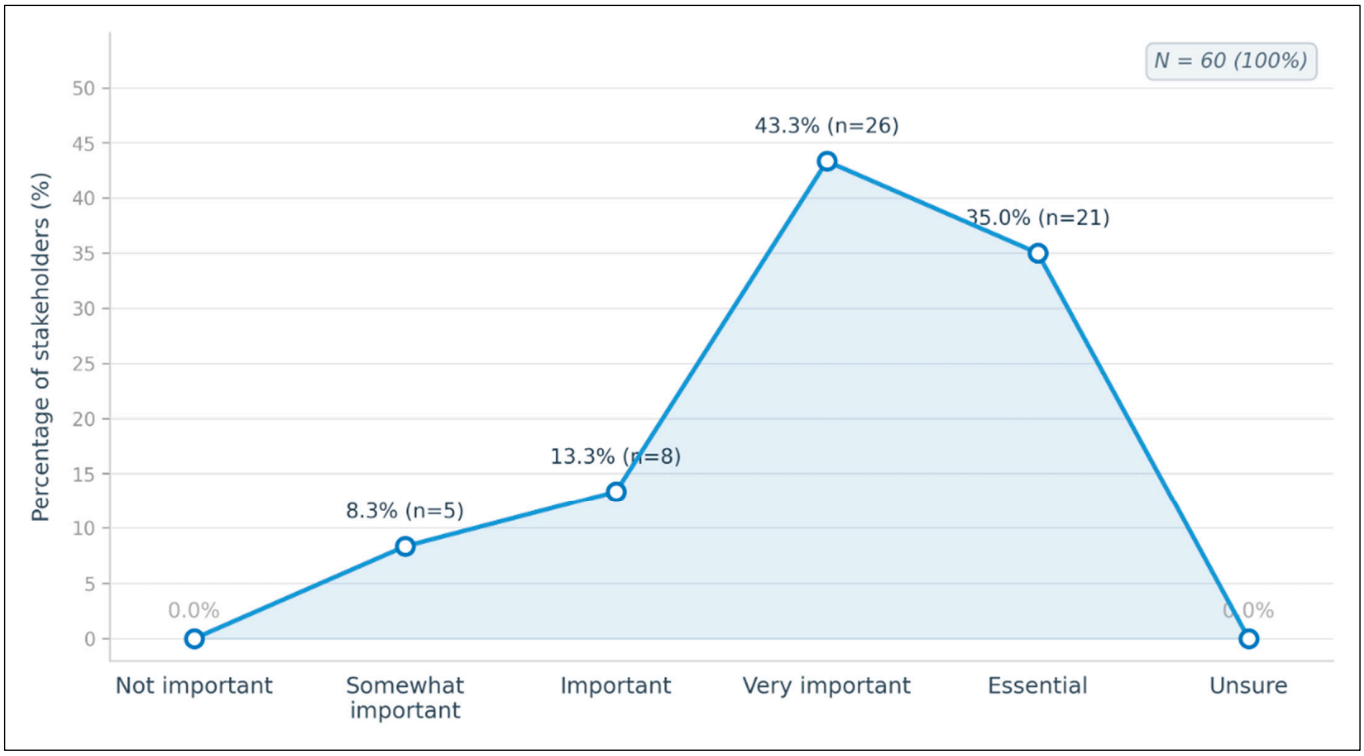


Figure 2. Importance of traceability for the stakeholders in the coffee supply chain.

- Future Consumer Demand for Traceability

We find highly significant differences ($p < 0.001$) in stakeholder expectations regarding future consumer demand for traceability. Most participants (95%, $n = 57$) expect that consumer requests for traceability will increase in the coming years. Among these, 76.7% ($n = 46$) express strong certainty that demand will increase, with Swiss stakeholders showing even higher confidence at 86.7% ($n = 26$) compared with Colombian stakeholders at 66.7% ($n = 20$). Only 5% ($n = 3$) remain unsure about future trends, and no participants expect demand to decrease.

- Current Traceability Technologies

The analysis of current technology adoption within the study sample shows significant variation ($p < 0.001$) across stakeholder groups and technology types. All participants utilize paper forms. Among Colombian stakeholders, 63.4% ($n = 19$) use a digital database, such as Excel or MySQL, whereas all Swiss stakeholders employ a digital database. Swiss stakeholders demonstrate a higher barcode or QR code use rate of 90% ($n = 27$) compared with 26.6% ($n = 8$) among Colombian stakeholders. Radio-frequency identification (RFID) technology is used to a limited extent: only 25% ($n = 15$) of all participants currently use it, mainly in Switzerland. No stakeholders report using other technologies, such as Blockchain, Internet of Things (IoT), or Artificial Intelligence (AI), for traceability.

- Priority Information for Traceability

This study identifies highly significant differences ($p < 0.001$) in the types of information stakeholders prioritize for traceability, depending on their specific roles in the coffee supply chain. The origin of coffee is recognized as the most important information to trace by 60% ($n = 36$) of surveyed stakeholders, with Swiss stakeholders showing notably higher emphasis at 66.7% ($n = 20$) compared with Colombian stakeholders at 53.3% ($n = 16$). The results reveal distinct information priorities aligned with stakeholder positions: farmers prioritize harvest date (83.3%, $n = 5$), local traders and millers focus on weight of coffee (33.3% and 50%, respectively), transporters emphasize delivery time (66.7%, $n = 4$), while exporters (100%, $n = 6$), importers (100%, $n = 10$), and the majority of roasters (50%, $n = 5$) and distributors (50%, $n = 5$) prioritize origin information.

4.1.2. Perception About Blockchain Technology—RQ2

Supplementary Materials present stakeholder perceptions of blockchain technology adoption for traceability. This section presents these results, addressing RQ2 by examining familiarity levels, understanding of blockchain capabilities, current usage, willingness to invest, likelihood of adoption, and perceptions of competitive advantage.

- Familiarity with Blockchain Technology

Blockchain familiarity remains low across the sample: 46.7% ($n = 28$) report no familiarity at all, 35% ($n = 21$) describe themselves as somewhat familiar, and only 18.3% ($n = 11$) claim familiarity, with no participant reporting being very familiar or having expert-level knowledge. These findings indicate a substantial knowledge gap that requires attention before widespread blockchain adoption can occur in the coffee supply chain. Figure 3 shows these results.

- Understanding of Blockchain Offerings

Despite limited familiarity, we find that among the few stakeholders who respond about blockchain capabilities, transparency is the most recognized feature. Among participants who expressed an opinion, 54.5% ($n = 6$ of 11) reported that blockchain enables transparency in the traces left by stakeholders. Additionally, 27.3% ($n = 3$ of 11) recognize

that blockchain guarantees veracity for stored information. However, 18.2% (n = 2 of 11 respondents) remain unsure about blockchain's offerings, and no participants identify stakeholder identification as a blockchain capability. The limited number of responses to this question reflects the overall low familiarity with blockchain technology.

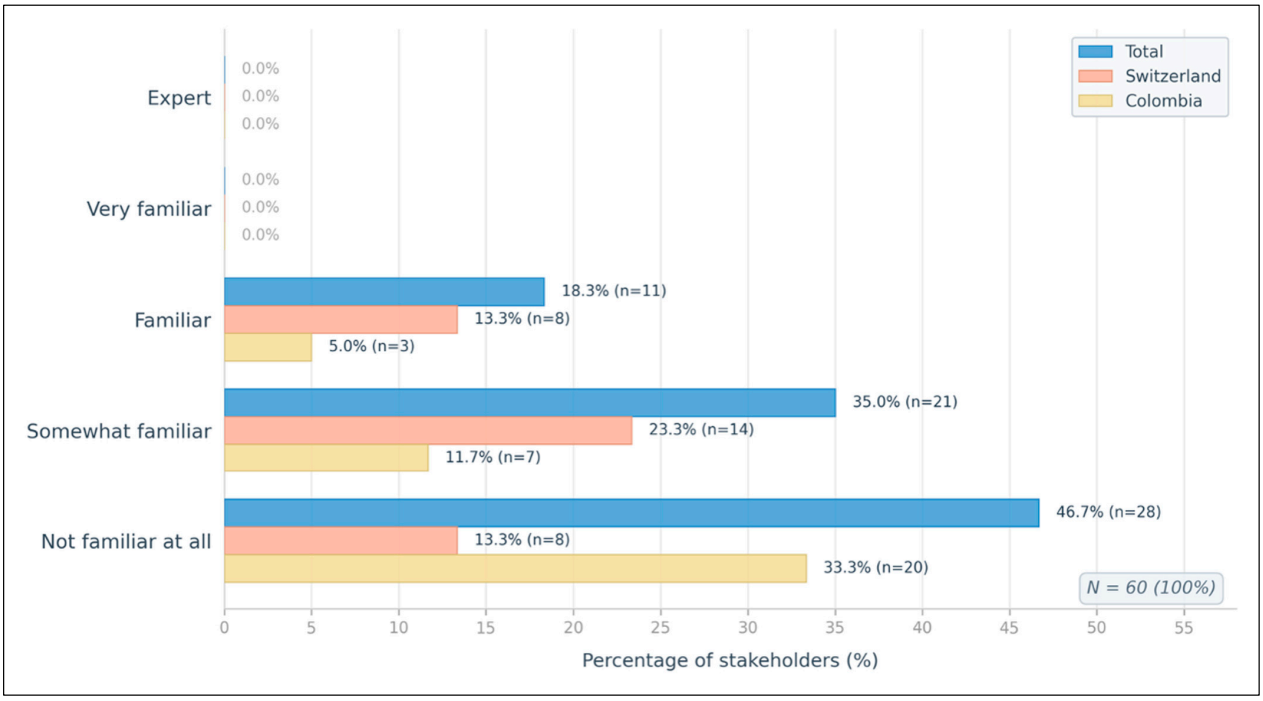


Figure 3. Familiarity with blockchain technology among coffee stakeholders.

- Current Blockchain Usage

The results indicate minimal current adoption of blockchain for coffee traceability. This research finds that no participant organizations currently use blockchain technology for traceability purposes (0%). However, 13.3% (n = 8) report planning to use blockchain technology in the future, suggesting emerging interest in adoption. Most stakeholders (80%; n = 48) neither use blockchain technology nor consider implementing it, while 6.7% (n = 4) remain unsure about their organization's stance. The analysis suggests that, among surveyed stakeholders, blockchain adoption in coffee supply chain traceability remains in very early stages.

- Investment Willingness

The intention to invest in blockchain suggests that while 48.3% (n = 29) accept low investment (less than 10% of the annual budget), 40% (n = 24) reject any investment entirely, and no stakeholder in either country is willing to commit moderate, high, or very high levels of resources (0%, n = 0 for the three categories). The remaining 11.7% (n = 7) report being unsure about investment decisions. These results indicate significant financial concerns and hesitancy regarding blockchain implementation costs.

- Likelihood of Blockchain Adoption

The perceived likelihood of blockchain adoption within the next ten years shows highly significant differences ($p < 0.001$) between stakeholder groups. The findings show that 30% (n = 18) of surveyed stakeholders consider blockchain adoption likely or very likely (23.3% likely, n = 14; and 6.7% very likely, n = 4), representing moderate optimism about future adoption. Additionally, 15% (n = 9) view adoption as neutral. Conversely, 6.7% (n = 4) perceive adoption as unlikely or very unlikely (5% unlikely, n = 3; and 1.7% very unlikely, n = 1). Only 1.7% (n = 1) remain unsure about the likelihood of adoption. Despite current

low implementation rates, these results suggest moderate optimism about blockchain's future role in coffee traceability, with most of the surveyed stakeholders maintaining neutral-to-positive expectations for widespread adoption within the next decade.

- Competitive Advantage Perception

The research finds mixed perceptions regarding the potential of blockchain to provide competitive advantages, with significant differences ($p < 0.001$) between Colombian and Swiss stakeholders. Among the 32 stakeholders who answered this question, 43.8% ($n = 14$) agree that implementing blockchain technology could lead to a competitive advantage, while 40.6% ($n = 13$) express uncertainty (maybe) about this topic. However, 12.5% ($n = 4$) disagree that blockchain would provide a competitive advantage, and 3.1% ($n = 1$) remain unsure. The results exhibit that Colombian stakeholders present more cautious perceptions, with 26.7% ($n = 8$) responding "agree" or "maybe", whereas Swiss stakeholders show higher confidence, with combined positive responses (agree and maybe) representing 59.4% ($n = 19$) of their answers.

4.1.3. Potential Benefits and Drawbacks of Blockchain Technology—RQ3

This section addresses RQ3 by examining potential benefits, drawbacks, barriers, and resources of blockchain technology for traceability in the coffee supply chain.

- Expected Benefits

Three benefits dominate stakeholder expectations. Improved transparency leads with 91.7% ($n = 55$) selection and, notably, this is the one benefit on which Colombian and Swiss stakeholders converge almost perfectly (90% vs. 93.3%, $p = 0.636$). While most perceptions in this survey diverge by geography, transparency's cross-context consensus suggests it functions as a foundational expectation that transcends stakeholder position and market environment. Table 1 presents the expected benefits for surveyed stakeholders by implementing blockchain technology for traceability in the coffee supply chain.

Table 1. Stakeholder expectations for potential benefits of blockchain technology for traceability in the coffee supply chain.

Question About Potential Benefits		Colombian Stakeholders						Swiss Stakeholders				*p*-Value *	OR (95% CI)
		Farmer	Local Trader	Miller	Transporter	Exporter	Total Col	Importer	Roaster	Distributor	Total Swi		
		n = 6	*n* = 6	*n* = 6	*n* = 6	*n* = 6	*n*= 30	*n* = 10	*n* = 10	*n* = 10	*n* = 30		
		n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)		
Which of the following benefits do you think blockchain technology could provide for traceability in the coffee supply chain? (Select all that apply) -Multi-response	Improved transparency	5 (8.3)	5 (8.3)	5 (8.3)	6 (10)	6 (10)	27 (45)	10 (16.7)	9 (15)	9 (15)	28 (46.7)	0.636 *	-
	Enhanced security	3 (5)	4 (6.7)	6 (10)	6 (10)	5 (8.3)	24 (40)	10 (16.7)	8 (13.3)	10 (16.7)	28 (46.7)	0.027 *	0.2 (0.05–1.5)
	Fraud prevention	5 (8.3)	5 (8.3)	5 (8.3)	6 (10)	6 (10)	27 (45)	10 (16.7)	7 (11.7)	9 (15)	26 (43.3)	0.308 *	-
	Streamlined processes	0 (0)	0 (0)	1 (1.7)	2 (3.3)	2 (3.3)	5 (8.3)	8 (13.3)	0 (0)	3 (5)	11 (18.3)	<0.001 *	3.0 (1.0–8.8)
	Better data management	0 (0)	0 (0)	0 (0)	0 (0)	3 (5)	3 (5)	10 (16.7)	0 (0)	5 (8.3)	15 (25)	<0.001 *	0.1 (0.2–0.4)
	Support for ethical and sustainable practices	3 (5)	3 (5)	2 (3.3)	0 (0)	1 (1.7)	9 (15)	10 (16.7)	2 (3.3)	5 (8.3)	17 (28.3)	<0.001 *	2.8 (0.8–9.7)
	Other	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-	-
	Unsure	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-	-

Note (%): all percentages in the table are calculated based on the total number of participants (denominator is N = 60). * *p*-value comparing the total of Colombian and Swiss stakeholders calculated by Fisher's exact test. OR $\leq$ 1: no association; between 1.1 and 2.4: low association; 2.5 and 3.9: moderate association; and $\geq$4: strong association.

Fraud prevention is the second most expected benefit, with 88.3% (n = 53) of surveyed stakeholders identifying it. Colombian stakeholders show slightly higher expectations for fraud prevention at 90% (n = 27) compared with Swiss stakeholders at 86.7% (n = 26), though this difference is not statistically significant (p = 0.308).

Enhanced security is recognized by 86.7% (n = 52) of surveyed stakeholders. This benefit shows a significant difference (p = 0.027) between groups, with Swiss stakeholders reporting higher expectations at 93.3% (n = 28) compared with Colombian stakeholders at 80% (n = 24).

Beyond the primary benefits, we identify additional operational advantages that stakeholders associate with blockchain technology. Support for ethical and sustainable practices is recognized by 43.3% (n = 26) of surveyed stakeholders, with a highly significant difference between groups ($p < 0.001$). Swiss stakeholders indicate substantially higher expectations for this benefit, at 56.7% (n = 17), compared with Colombian stakeholders, at 30% (n = 9).

Better data management emerges as an expected benefit for 30% (n = 18) of all participants, showing highly significant differences ($p < 0.001$) between stakeholder groups. Swiss stakeholders exhibit stronger expectations for data management improvements at 50% (n = 15), while Colombian stakeholders show considerably lower expectations at 10% (n = 3).

Streamlined processes represent an anticipated benefit for 26.7% (n = 16) of surveyed stakeholders, with highly significant differences ($p < 0.001$) between groups. Swiss stakeholders present notably higher expectations, at 36.7% (n = 11), compared with Colombian stakeholders, at 16.7% (n = 5). Figure 4 exhibits the responses from all participants for the expected benefits.

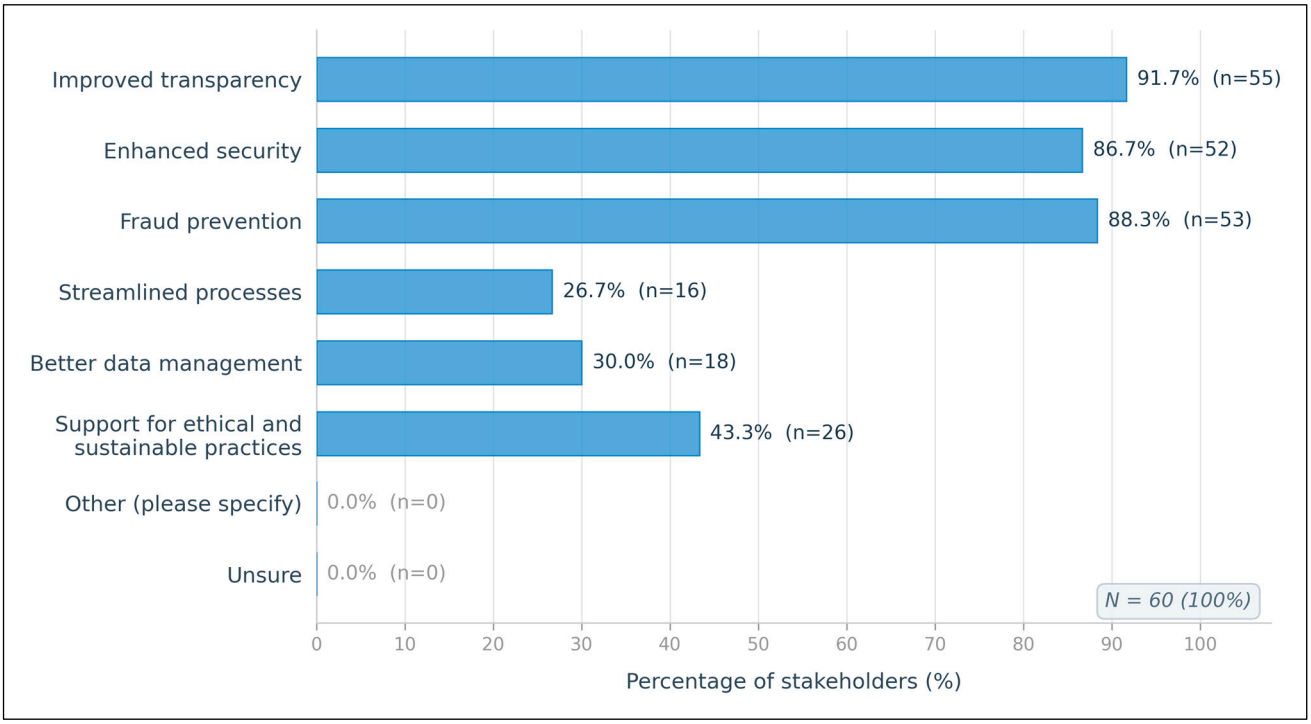


Figure 4. Expected benefits among stakeholders by implementing blockchain technology for traceability in the coffee supply chain.

- Potential Drawbacks

High implementation costs are the most prevalent concern, identified by 95% (n = 57) of all stakeholders, with no significant geographic difference (96.7% in Colombia vs. 93.3%

in Switzerland, $p = 0.269$). Like transparency on the benefits side, cost concern represents a cross-context consensus. The parallel between these two consensus items is noteworthy: stakeholders universally agree on both the primary benefit (transparency) and the primary barrier (cost), which frames the adoption decision as a cost-transparency trade-off that policy and industry interventions may need to address directly. Table 2 presents the expected drawbacks for surveyed stakeholders of implementing blockchain technology for traceability in the coffee supply chain.

Table 2. Stakeholder expectations for potential drawbacks of blockchain technology for traceability in the coffee supply chain.

Question About Potential Drawbacks		Colombian Stakeholders						Swiss Stakeholders				*p*-Value *	OR (95% CI)
		Farmer	Local Trader	Miller	Transporter	Exporter	Total Col	Importer	Roaster	Distributor	Total Swi		
		n = 6	*n* = 6	*n* = 6	*n* = 6	*n* = 6	*n* = 30	*n* = 10	*n* = 10	*n* = 10	*n* = 30		
		n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)		
What do you perceive as the main drawbacks of using blockchain technology for traceability in the coffee industry? -Multi-response	High implementation costs	5 (8.3)	6 (10)	6 (10)	6 (10)	6 (10)	29 (48.3)	10 (16.7)	8 (13.3)	10 (16.7)	28 (46.7)	0.269 *	-
	Limited understanding and expertise	5 (8.3)	5 (8.3)	6 (10)	6 (10)	6 (10)	28 (46.7)	10 (16.7)	7 (11.7)	10 (16.7)	27 (45)	0.123 *	-
	Interoperability and standardization issues	0 (0)	0 (0)	0 (0)	1 (1.7)	2 (3.3)	3 (5)	9 (15)	4 (6.7)	5 (8.3)	18 (30)	<0.001 *	0.1 (0.3–0.4)
	Data privacy concerns	0 (0)	0 (0)	1 (1.7)	2 (3.3)	3 (5)	6 (10)	10 (16.7)	3 (5)	7 (11.7)	20 (33.3)	<0.001 *	0.08 (0.02–0.3)
	Scalability issues	0 (0)	0 (0)	0 (0)	2 (3.3)	1 (1.7)	3 (5)	7 (11.7)	3 (5)	2 (3.3)	12 (20)	0.006 *	6.0 (1.4–24.2)
	Legal and regulatory challenges	1 (1.7)	0 (0)	0 (0)	3 (5)	2 (3.3)	6 (10)	7 (11.7)	5 (8.3)	2 (3.3)	14 (23.3)	0.008 *	0.2 (0.09–0.8)
	Other	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-	-
	Unsure	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-	-

Note (%): all percentages in the table are calculated based on the total number of participants (denominator is N = 60). * *p*-value comparing the total of Colombian and Swiss stakeholders calculated by Fisher's exact test. OR ≤ 1: no association; between 1.1 and 2.4: low association; 2.5 and 3.9: moderate association; and ≥4: strong association.

Limited understanding and expertise emerge as the second-most-recognized drawback, with 91.7% ($n = 55$) of all surveyed stakeholders expressing this concern. Colombian stakeholders report this drawback at 93.3% ($n = 28$), slightly higher than Swiss stakeholders at 90% ($n = 27$), though the difference is not statistically significant ($p = 0.123$).

Data privacy concerns represent a significant drawback for 43.3% ($n = 26$) of all participants, with a highly significant difference between groups ($p < 0.001$). Swiss stakeholders demonstrate substantially greater concern about data privacy, at 66.7% ($n = 20$), compared with Colombian stakeholders at 20% ($n = 6$).

Interoperability and standardization issues concern 35% ($n = 21$) of surveyed stakeholders, with highly significant differences between groups ($p < 0.001$). Swiss stakeholders express considerably greater concern about this challenge, at 60% ($n = 18$), compared with Colombian stakeholders, at 10% ($n = 3$).

Legal and regulatory challenges represent a concern for 33.3% ($n = 20$) of all participants, with significant differences ($p = 0.008$) between stakeholder groups. Swiss stakeholders show greater concern, at 46.7% ($n = 14$), compared with Colombian stakeholders, at 20% ($n = 6$).

Scalability issues concern 25% ($n = 15$) of surveyed stakeholders, with significant differences ($p = 0.006$) between groups. Swiss stakeholders express notably greater concern

about scalability, at 40% (n = 12), compared with Colombian stakeholders, at 10% (n = 3). Figure 5 exhibits the responses from all participants for the perceived drawbacks.

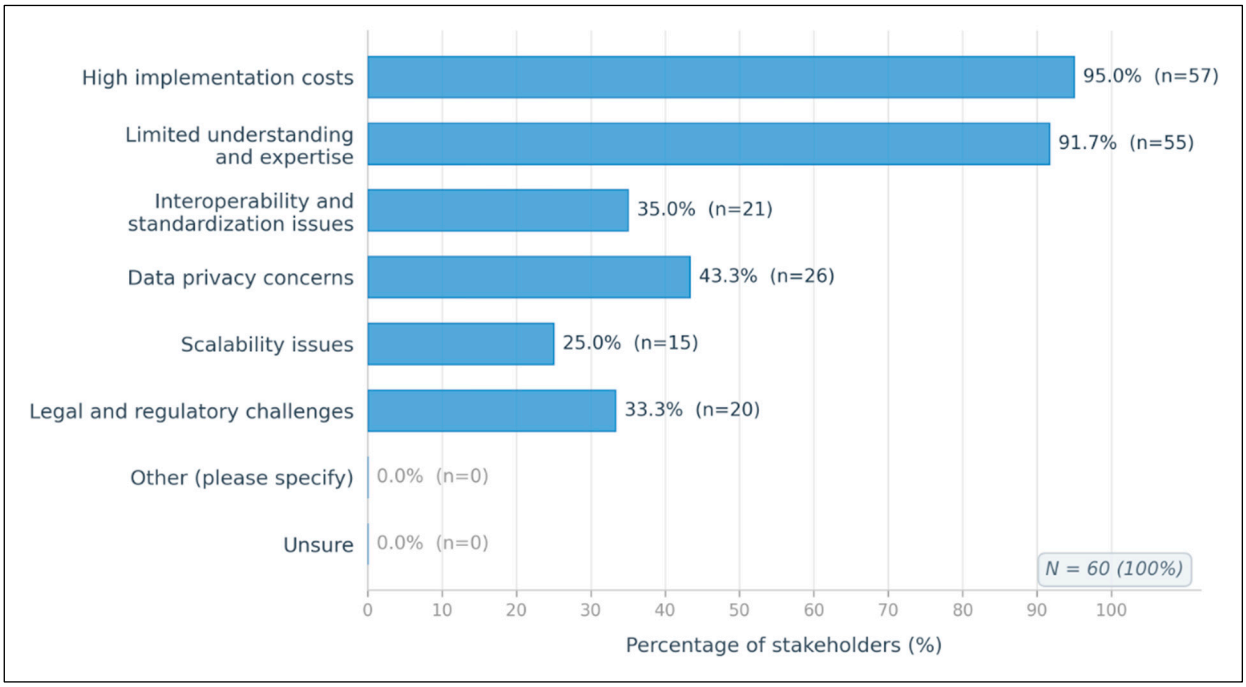


Figure 5. Perceived drawbacks among stakeholders of implementing blockchain technology for traceability in the coffee supply chain.

- Barriers to Adoption

Three barriers form a reinforcing triad: lack of awareness and understanding (93.3%, n = 56), high implementation costs (90%, n = 54), and technical complexity (86.7%, n = 52). Rather than independent obstacles, these three barriers likely interact; limited awareness reduces the ability to assess costs accurately, which in turn amplifies perceptions of technical complexity.

Concerns about data privacy and security constitute a barrier for 46.7% (n = 28) of all participants. Legal and regulatory challenges present obstacles for 31.7% (n = 19) of surveyed stakeholders. Resistance to change emerges as a barrier for 20% (n = 12) of all participants. No stakeholders identified other barriers or expressed uncertainty (0% for both categories, n = 0). Table 3 presents the expected barriers to implementing blockchain technology for traceability in the coffee supply chain, as reported by surveyed stakeholders.

- Required Resources for Implementation

This research finds that training and education programs arise as the most critical resource need, with 93.3% (n = 56) of all participants identifying this requirement. Financial incentives or funding represent essential support for 86.7% (n = 52) of the studied sample. Access to technical expertise constitutes a necessary resource for 85% (n = 51) of surveyed stakeholders.

Government support and regulations emerge as important for 81.7% (n = 49) of all participants. Industry-wide collaboration and partnerships represent valuable resources for 48.3% (n = 29) of surveyed stakeholders. Research and development initiatives are recognized by 35% (n = 21) of all participants. No stakeholders select other resources or express uncertainty (0%, n = 0 for both categories).

Table 3. Stakeholder expectations for potential barriers to blockchain technology for traceability in the coffee supply chain.

Question About Potential Barriers		Colombian Stakeholders						Swiss Stakeholders				*p*-Value *	OR (95% CI)
		Farmer	Local Trader	Miller	Transporter	Exporter	Total Col	Importer	Roaster	Distributor	Total Swi		
		n = 6	*n* = 6	*n* = 6	*n* = 6	*n* = 6	*n* = 30	*n* = 10	*n* = 10	*n* = 10	*n* = 30		
		n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)		
In your opinion, what are the most significant barriers to the adoption of blockchain technology for traceability in the coffee supply chain? -Multi-response	Lack of awareness and understanding	5 (8.3)	5 (8.3)	5 (8.3)	6 (10)	6 (10)	27 (45)	10 (16.7)	9 (15)	10 (16.7)	29 (48.3)	0.464 *	-
	Technical complexity	3 (5)	5 (8.3)	5 (8.3)	6 (10)	6 (10)	25 (41.7)	10 (16.7)	7 (11.7)	10 (16.7)	27 (45)	0.027 *	1.8 (0.3–8.3)
	High implementation costs	4 (6.7)	5 (8.3)	5 (8.3)	6 (10)	6 (10)	26 (43.3)	10 (16.7)	8 (13.3)	10 (16.7)	28 (46.7)	0.159 *	-
	Resistance to change	1 (1.7)	0 (0)	0 (0)	1 (1.7)	3 (5)	5 (8.3)	4 (6.7)	3 (5)	0 (0)	7 (11.7)	0.033 *	1.5 (0.4–5.4)
	Legal and regulatory challenges	1 (1.7)	1 (1.7)	1 (1.7)	2 (3.3)	3 (5)	8 (13.3)	5 (8.3)	5 (8.3)	1 (1.7)	11 (18.3)	0.289 *	-
	Concerns about data privacy and security	0 (0)	0 (0)	1 (1.7)	2 (3.3)	3 (5)	6 (10)	10 (16.7)	5 (8.3)	7 (11.7)	22 (36.7)	<0.001 *	0.1 (0.03–0.3)
	Other	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-	-
	Unsure	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-	-

Note (%): all percentages in the table are calculated based on the total number of participants (denominator is N = 60). * *p*-value comparing the total of Colombian and Swiss stakeholders calculated by Fisher's exact test. OR ≤ 1: no association; between 1.1 and 2.4: low association; 2.5 and 3.9: moderate association; and ≥4: strong association.

- Main Aspects to Reduce through Blockchain Implementation

We identify significant differences ($p = 0.041$) in surveyed stakeholder objectives regarding the most important aspects to reduce in the coffee supply chain through blockchain-based traceability. Cost reduction appears to be the predominant objective among all participants, with 53.3% ($n = 32$) identifying it as the primary area for reduction. Colombian stakeholders demonstrate particularly strong emphasis on cost reduction at 63.3% ($n = 19$), while Swiss stakeholders report 43.3% ($n = 13$). Time reduction represents the second most important objective, recognized by 18.3% ($n = 11$) of all participants, with Swiss participants showing notably higher interest at 26.7% ($n = 8$) compared with Colombian stakeholders at 10% ($n = 3$).

Process reduction constitutes an objective for 15% ($n = 9$) of all participants, with Swiss stakeholders showing substantially higher interest at 23.3% ($n = 7$) compared with 6.7% ($n = 2$) for Colombian stakeholders. Paper forms reduction receives recognition from 8.3% ($n = 5$) of surveyed stakeholders, predominantly from Colombian participants at 13.3% ($n = 4$). Fraud reduction represents an objective for only 5% ($n = 3$) of all participants. Notably, no stakeholders identify staff reduction as an objective (0%, $n = 0$), suggesting human resources are not viewed as an area for reduction through blockchain implementation. Similarly, no participants select "other" objectives or express uncertainty (0%, $n = 0$ for both categories).

- Main Aspects to Increase through Blockchain Implementation

Significant differences ($p = 0.029$) are observed in stakeholders' objectives regarding the most important aspects to increase through the implementation of blockchain technology for traceability in the studied coffee supply chain. The primary motivation among surveyed

stakeholders is increasing sales, with 48.3% (n = 29) selecting this objective. Colombian stakeholders place particular emphasis on sales increases at 56.7% (n = 17), while Swiss stakeholders report 40% (n = 12).

Transparency improvement emerges as the second most important objective, with 20% (n = 12) of all participants, predominantly Swiss participants at 30% (n = 9), compared with 10% (n = 3) for Colombian stakeholders. An increase in market share is an objective for 15% (n = 9) of all participants, with Swiss stakeholders showing higher interest at 23.3% (n = 7). Notably, no stakeholders identify customer satisfaction as a primary objective, suggesting this may be viewed as an indirect consequence of other objectives rather than a direct goal. Table 4 presents the surveyed stakeholders' expectations for resources to help successful blockchain implementation for traceability in the coffee supply chain.

Table 4. Stakeholder expectations for resources helping successful blockchain technology implementation for traceability in the coffee supply chain.

Question About Resources		Colombian Stakeholders						Swiss Stakeholders				*p*-Value *,**	OR (95% CI)
		Farmer	Local Trader	Miller	Transporter	Exporter	Total Col	Importer	Roaster	Distributor	Total Swi		
		n = 6	*n* = 6	*n* = 6	*n* = 6	*n* = 6	*n* = 30	*n* = 10	*n* = 10	*n* = 10	*n* = 30		
		n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)		
Which of the following resources or support do you think would be most helpful for the successful implementation of blockchain technology in the coffee supply chain? -Multi-response	Financial incentives or funding	6 (10)	6 (10)	6 (10)	5 (8.3)	4 (6.7)	27 (45)	10 (16.7)	6 (10)	9 (15)	25 (41.7)	0.049 *	1.8 (0.3–8.3)
	Training and education programs	5 (8.3)	5 (8.3)	6 (10)	6 (10)	6 (10)	28 (46.7)	10 (16.7)	8 (13.3)	10 (16.7)	28 (46.7)	0.285 *	-
	Industry-wide collaboration and partnerships	1 (1.7)	1 (1.7)	3 (5)	4 (6.7)	3 (5)	12 (20)	8 (13.3)	3 (5)	6 (10)	17 (28.3)	0.090 *	-
	Government support and regulations	6 (10)	6 (10)	6 (10)	6 (10)	4 (6.7)	28 (46.7)	6 (10)	7 (11.7)	8 (13.3)	21 (35)	0.054 *	6.0 (1.1–30.7)
	Access to technical expertise	2 (3.3)	5 (8.3)	5 (8.3)	6 (10)	6 (10)	24 (40)	10 (16.7)	7 (11.7)	10 (16.7)	27 (45)	0.005 *	0.4 (0.1–1.9)
	Research and development initiatives	0 (0)	0 (0)	0 (0)	1 (1.7)	5 (8.3)	6 (10)	7 (11.7)	4 (6.7)	4 (6.7)	15 (25)	<0.001 *	4.0 (1.2–12.5)
	Other	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-	-
	Unsure	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-	-
Which of the following aspects do you consider as the most important to reduce in the coffee supply chain by applying blockchain technology for traceability? -Single-response	To reduce time	0 (0)	0 (0)	0 (0)	2 (3.3)	1 (1.7)	3 (5)	2 (3.3)	2 (3.3)	4 (6.7)	8 (13.3)		**Cramer's V (95% CI)**
	To reduce costs	5 (8.3)	4 (6.7)	4 (6.7)	4 (6.7)	2 (3.3)	19 (31.7)	2 (3.3)	6 (10)	5 (8.3)	13 (21.7)		
	To reduce processes	0 (0)	0 (0)	1 (1.7)	0 (0)	1 (1.7)	2 (3.3)	6 (10)	1 (1.7)	0 (0)	7 (11.7)		
	To reduce paper forms	1 (1.7)	1 (1.7)	1 (1.7)	0 (0)	1 (1.7)	4 (6.7)	0 (0)	0 (0)	1 (1.7)	1 (1.7)	0.041 **	0.37 (0.23–0.62)
	To reduce staff	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)		
	To reduce fraud	0 (0)	1 (1.7)	0 (0)	0 (0)	1 (1.7)	2 (3.3)	0 (0)	1 (1.7)	0 (0)	1 (1.7)		
	Other	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)		
	Unsure	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)		

Table 4. *Cont.*

Question About Resources		Colombian Stakeholders						Swiss Stakeholders				*p*-Value *,**	OR (95% CI)
		Farmer	Local Trader	Miller	Transporter	Exporter	Total Col	Importer	Roaster	Distributor	Total Swi		
		n = 6	*n* = 6	*n* = 6	*n* = 6	*n* = 6	*n* = 30	*n* = 10	*n* = 10	*n* = 10	*n* = 30		
		n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)		
Which of the following aspects do you consider as the most important to increase in the coffee supply chain by applying blockchain technology for traceability? -Single-response	To increase sales	3 (5)	5 (8.3)	4 (6.7)	4 (6.7)	1 (1.7)	17 (28.3)	4 (6.7)	3 (5)	5 (8.3)	12 (20)	0.029 **	0.41 (0.26–0.65)
	To increase customer satisfaction	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)		
	To increase market share	0 (0)	0 (0)	0 (0)	0 (0)	2 (3.3)	2 (3.3)	5 (8.3)	1 (1.7)	1 (1.7)	7 (11.7)		
	To increase stakeholders' cooperation	1 (1.7)	1 (1.7)	1 (1.7)	1 (1.7)	1 (1.7)	5 (8.3)	0 (0)	1 (1.7)	0 (0)	1 (1.7)		
	To increase transparency	0 (0)	0 (0)	0 (0)	1 (1.7)	2 (3.3)	3 (5)	1 (1.7)	4 (6.7)	4 (6.7)	9 (15)		
	To increase the information about the product	2 (3.3)	0 (0)	1 (1.7)	0 (0)	0 (0)	3 (5)	0 (0)	1 (1.7)	0 (0)	1 (1.7)		
	Other	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)		
	Unsure	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)		

Note (%): all percentages in the table are calculated based on the total number of participants (denominator is N = 60). * *p*-value comparing the total of Colombian and Swiss stakeholders calculated by Fisher's exact test. ** Calculated by likelihood ratio. OR $\leq$ 1: no association; between 1.1 and 2.4: low association; 2.5–3.9: moderate association; and $\geq$4: strong association. Cramer's V: between 0 and 0.09: no association; 0.10 and 0.30: low association; 0.31 and 0.50: moderate association; and >0.50: strong association.

Taken together, the benefit and drawback profiles reveal an asymmetric perception structure. On the benefits side, transparency, fraud prevention, and security achieve near-consensus levels above 85%, while additional benefits such as ethical practices (43.3%) and data management (30%) show significant geographic variation. On the drawbacks side, costs and lack of expertise similarly achieve near-consensus at over 90%, while secondary concerns such as data privacy (43.3%) and legal challenges (33.3%) are more context-dependent. This asymmetry suggests that the core advantages and core barriers of blockchain are perceived consistently across contexts, whereas the secondary benefits and drawbacks are shaped by local priorities, a pattern with implications for the design of context-specific implementation strategies.

4.1.4. Classification of Benefits and Drawbacks According to Operational and Business Dimensions

This section addresses RQ4 by classifying the identified benefits and drawbacks according to their impact on specific operational and business dimensions. The classification draws on quantitative results from the surveyed participants, presented in previous sections, and organizes them into meaningful categories that reflect their implications for coffee supply chain operations. We consider nine dimensions for the analysis: time, cost, process, staff, consumer satisfaction, sales, market share, transparency and information, and cooperation and collaboration. We describe the benefits and drawbacks of each dimension

hereafter; however, all these findings are exploratory within the studied sample and require empirical validation through implementation and longitudinal studies.

- Time Dimension

Benefits: Streamlined processes, recognized by 26.7% of all participants, are directly associated with improved time efficiency. Blockchain technology offers the potential to reduce verification times and accelerate information flow across the supply chain through automated processes and access to unalterable data.

Drawbacks: The technical complexity barrier, identified by 86.7% of surveyed stakeholders, indicates substantial time requirements for system implementation and stakeholder training. Additionally, interoperability and standardization issues, recognized by 35% of all participants, indicate potential delays in establishing compatible systems among diverse supply chain actors.

- Cost Dimension

Benefits: Fraud prevention, expected by 88.3% of surveyed stakeholders, offers significant cost-saving potential by reducing financial losses from counterfeit products and fraudulent transactions. Enhanced security, anticipated by 86.7% of all participants, contributes to cost reduction by minimizing security breaches and associated recovery expenses.

Drawbacks: High implementation costs are the dominant concern, recognized by 95% of surveyed stakeholders. This finding shows universal acknowledgment that blockchain adoption requires substantial financial investment. The need for financial incentives or funding, identified by 86.7% of all participants, further emphasizes the significant capital requirements for successful implementation. Scalability issues, concerning 25% of participants, suggest potential ongoing costs for system expansion and maintenance.

- Process Dimension

Benefits: Improved transparency, the most widely expected benefit at 91.7%, fundamentally enhances process visibility and accountability throughout the supply chain. Better data management, anticipated by 30% of surveyed stakeholders, improves process efficiency through enhanced information organization and accessibility. Streamlined processes, recognized by 26.7% of all participants, directly address process optimization by automating and reducing manual interventions.

Drawbacks: Limited understanding and expertise, identified by 91.7% of surveyed stakeholders, present substantial obstacles to effective process integration and utilization. Interoperability and standardization issues, recognized by 35% of participants, create challenges for seamless process integration across diverse supply chain stages and stakeholder systems.

- Staff Dimension

Benefits: While not explicitly measured as a separate benefit category, the surveyed stakeholder expectation for streamlined processes (26.7%) suggests a perceived potential for reduced manual workload and enhanced staff efficiency through automated verification and data management functions.

Drawbacks: The lack of awareness and understanding, identified as the primary barrier by 93.3% of surveyed stakeholders, directly relates to staff capability gaps. The critical need for training and education programs, recognized by 93.3% of participants, demonstrates the substantial investment required in human resource development. Access to technical expertise, deemed necessary by 85% of surveyed stakeholders, highlights specialized knowledge gaps among current staff.

- Consumer Satisfaction Dimension

Benefits: Support for ethical and sustainable practices, anticipated by 43.3% of surveyed stakeholders, directly contributes to consumer satisfaction by addressing growing consumer demands for sustainable and ethical sourcing. Improved transparency (91.7%) and fraud prevention (88.3%) are expected by participants to enhance consumer confidence and trust in product authenticity and quality claims, thereby potentially increasing satisfaction levels.

Drawbacks: We find no direct drawbacks specifically impacting consumer satisfaction. However, data privacy concerns, recognized by 43.3% of surveyed stakeholders, could potentially affect consumer trust if not properly addressed through appropriate data protection measures.

- Sales Dimension

Benefits: Increasing sales represents the primary objective for implementing blockchain for traceability among 48.3% of surveyed stakeholders. Improved transparency (91.7%), fraud prevention (88.3%), and enhanced security (86.7%) are perceived by participants as collectively contributing to consumer trust, which they expect could translate into sales increases. Also, support for ethical and sustainable practices (43.3%) is perceived as addressing market demands that could drive purchasing decisions and expand the customer base.

Drawbacks: Participants perceive that high implementation costs (95%) may create financial barriers that limit adoption, potentially resulting in competitive disadvantages for those unable to invest in blockchain technology. The resistance to change, identified by 20% of all participants, is perceived as a factor that may slow adoption rates and create market segmentation between technologically advanced and traditional operators.

- Market Share Dimension

Benefits: Increase in market share; 15% of surveyed stakeholders identify it as an objective for implementing blockchain traceability. The perception of competitive advantage, expressed by 43.3% of participants, suggests they expect that blockchain adoption could enable market differentiation. Surveyed stakeholders perceive that improved transparency (91.7%) and support for ethical and sustainable practices (43.3%) may position adopters favorably in markets where consumers increasingly value these attributes.

Drawbacks: The significant differences between Colombian and Swiss stakeholders in their recognition of benefits and drawbacks suggest potential risks of market segmentation. Participants perceive that high implementation costs (95%) and limited understanding (91.7%) could create barriers to entry, thereby consolidating market power among larger, better-resourced organizations, and potentially disadvantaging smaller stakeholders.

- Transparency and Information Dimension

Benefits: Improved transparency appears as the paramount benefit, recognized by 91.7% of surveyed stakeholders, representing the highest consensus among all identified advantages. This benefit directly addresses the current moderate levels of trust reported by 63.3% of all participants. Better data management, expected by 30% of participants, enhances information quality, accessibility, and reliability throughout the supply chain. The objective of increasing transparency, identified by 20% of participants, demonstrates explicit stakeholder interest in improving information visibility.

Drawbacks: Limited understanding and expertise (reported by 91.7% of participants) pose significant challenges to effective information management and interpretation. Data privacy concerns (43.3%) create tensions between transparency objectives and confidentiality requirements, particularly affecting Swiss stakeholders (66.7%), who express substantially greater concern about privacy issues than Colombian stakeholders (20%).

- Cooperation and Collaboration Dimension

Benefits: Stakeholder cooperation increases as an objective for 10% of all participants, suggesting recognition of blockchain's potential to enhance collaborative relationships. The need for industry-wide collaboration and partnerships, recognized by 48.3% of surveyed stakeholders, reflects awareness that blockchain's benefits extend beyond individual organizations.

Drawbacks: The lack of awareness and understanding (selected by 93.3% of participants) creates fundamental obstacles to establishing collaborative blockchain networks. Legal and regulatory challenges (33.3%) complicate cross-border and multi-stakeholder cooperation efforts. The need for government support and regulations, identified by 81.7% of all participants, demonstrates that successful collaboration requires institutional frameworks that currently may not exist.

Figure 6 summarizes the classification of the benefits and drawbacks in our research.

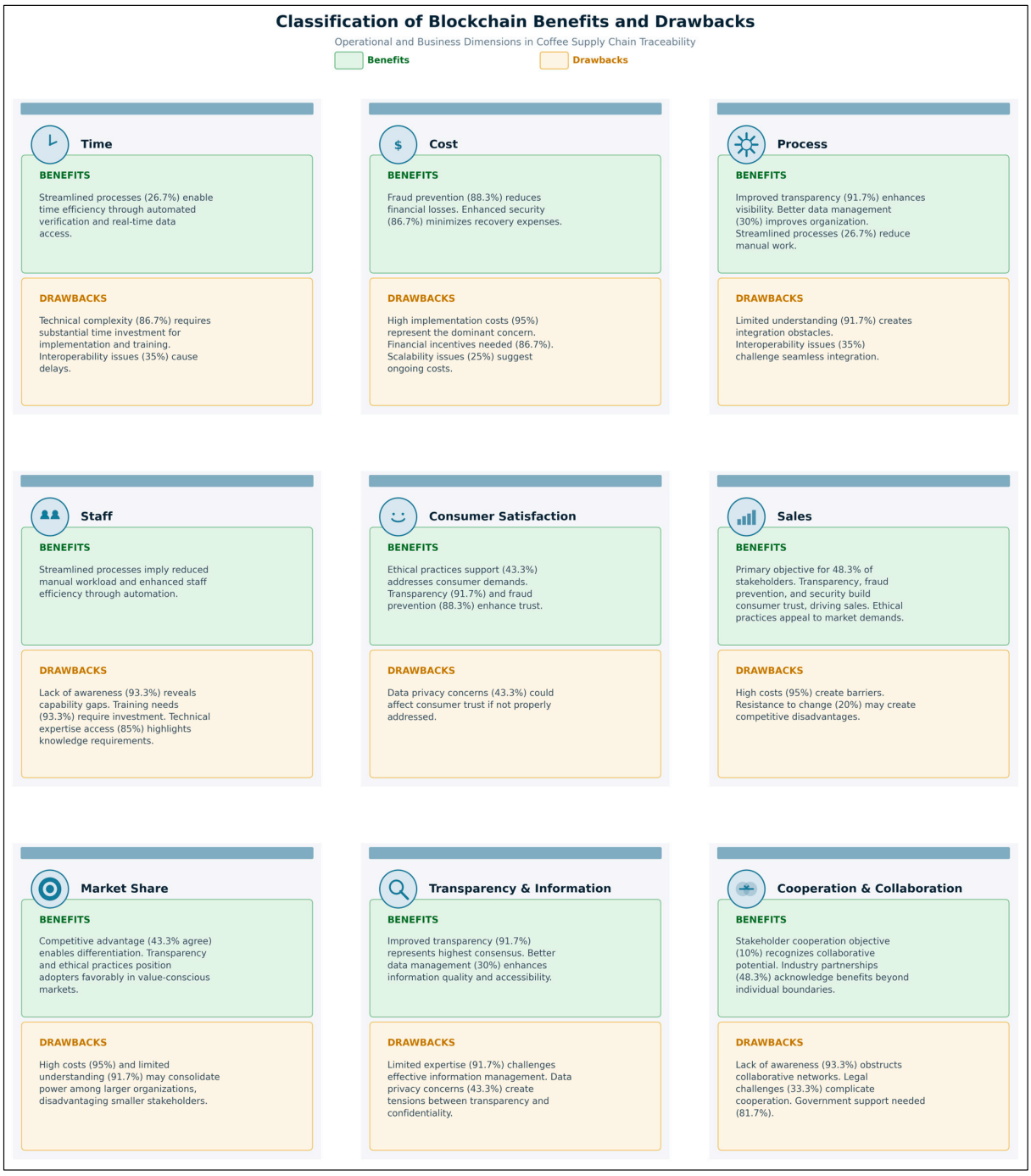


Figure 6. Classification of the benefits and drawbacks of blockchain technology for traceability.

The results for companies show that the stakeholder sample population broadly recognizes blockchain's potential (particularly for transparency and fraud prevention) but faces substantial barriers related to cost, knowledge, and institutional support. The results for consumers, in the next section, provide a complementary demand-side perspective on whether and how end consumers value the blockchain traceability benefits identified by the surveyed companies.

4.2. Results for Consumers

This section presents findings from a consumer survey of 300 coffee consumers in Switzerland. The second instrument addresses demographic characteristics; RQ1 (questions 3–5) regarding consumer perceptions of traceability; and RQ2 (questions 6–10) concerning their opinions on the use of blockchain-based traceability systems, willingness to pay for it, and intention to tip farmers. Table 5 presents these results.

Table 5. Results from the consumer survey on perceptions of traceability and blockchain.

Questions (Single-Response)		No. Swiss Consumers n = 300	Relative Frequency %	p-Value †,††
Are you female or male?	Female	154	51.3	0.686 ††
	Male	146	48.7	
	Prefer not to say	0	0	
What is your age?	Less than 25	52	17.3	<0.001 †
	Between 25 and 50	154	51.3	
	More than 50	94	31.3	
	Prefer not to say	0	0	
Would you like to know information about the provenance of the coffee you are drinking and its journey to your hand? For instance, harvest time, transport conditions, roasting temperature…	Yes, I am interested	188	62.7	<0.001 †
	No, I am not interested	59	19.7	
	I am already getting this information	20	6.7	
	I think it is not necessary	20	6.7	
	Unsure	13	4.3	
How do you think you can get this information today?	Certificated labels on your coffee	95	31.7	<0.001 †
	Reports from coffee-selling companies	30	10	
	Searching online	143	47.7	
	Unsure	32	10.7	
How would you rate the current level of trust in the information about the provenance of the coffee you are drinking and its journey to your hand?	Very low	24	8	<0.001 †
	Low	55	18.3	
	Moderate	146	48.7	
	High	54	18	
	Very high	10	3.3	
	Unsure	11	3.7	
Have you heard about blockchain technology?	Yes, but a little bit	159	53	<0.001 †
	Yes, I consider myself an expert on it	37	12.3	
	No, I have never heard about it	92	30.7	
	Unsure	12	4	
Would you be willing to pay extra money to get information about the provenance of the coffee you are drinking and its journey to your hand through a transparent, verifiable, and reliable system?	Yes, I am interested	50	16.7	<0.001 †
	Maybe	120	40	
	No, I am not interested	119	39.7	
	Unsure	11	3.7	
How much are you willing to pay to get information about the provenance of the coffee you are drinking and its journey to your hand through a transparent, verifiable, and reliable system?	Less than 5 CHF	85	28.3	<0.001 †
	Between 5 and 10 CHF	45	15	
	More than 10 CHF	25	8.3	
	Unsure	39	13	
	I would not pay	106	35.3	
Would you like to send a tip directly to the farmer of the coffee you are drinking through a transparent, verifiable, and reliable system?	Yes, I am interested	61	20.3	<0.001 †
	Maybe	116	38.7	
	No, I am not interested	101	33.7	
	Unsure	22	7.3	
How much would you like to tip the farmer for your coffee through a transparent, verifiable, and reliable system?	Less than 5 CHF	92	30.7	<0.001 †
	Between 5 and 10 CHF	66	22	
	More than 10 CHF	16	5.3	
	Unsure	45	15	
	I would not tip	81	27	

Note (%): all percentages in the table are calculated based on the total number of participants (denominator is N = 300). † p-value calculated by nonparametric asymptotic chi-square test. †† Calculated by binomial test. CHF = Confoederatio Helvetica Franc.

4.2.1. Consumers' Characteristics and Perception About Traceability—RQ1

We identify a balanced gender distribution among consumers, with 51.3% (n = 154) female and 48.7% (n = 146) male participants, showing no significant difference (p = 0.686). Regarding age distribution, the results reveal highly significant differences ($p < 0.001$) across age groups. Most consumers, 51.3% (n = 154), are in the 25–50 age range, followed by 31.3% (n = 94) over 50, and 17.3% (n = 52) under 25.

The analysis reveals highly significant differences ($p < 0.001$) in consumer interest regarding provenance information. The 62.7% (n = 188) of consumers are interested in information about coffee provenance and its journey, including details such as harvest time, transport conditions, and roasting temperature. Conversely, 19.7% (n = 59) report no interest in this information, while 6.7% (n = 20) indicate they are already receiving such information. Additionally, 6.7% (n = 20) consider traceability information unnecessary, and 4.3% (n = 13) remain unsure.

Regarding current access methods for provenance information, the findings show highly significant differences ($p < 0.001$) in consumer preferences. Online searching is the most preferred method, with 47.7% (n = 143) of consumers selecting it. Certificated labels on coffee packages represent the second-most preferred option at 31.7% (n = 95), followed by reports from coffee-selling companies at 10% (n = 30). Notably, 10.7% (n = 32) remain unsure about access methods.

Highly significant differences ($p < 0.001$) are observed in consumer trust for current provenance information. The predominant response indicates moderate trust, with 48.7% (n = 146) of consumers rating their trust as such. Lower trust characterizes a substantial portion of consumers, with 18.3% (n = 55) rating trust as low and 8% (n = 24) as very low. Higher trust levels are underrepresented: 18% (n = 54) rate trust as high, and only 3.3% (n = 10) as very high. Additionally, 3.7% (n = 11) remain unsure about their trust levels.

4.2.2. Consumers' Perception About Blockchain-Based Traceability Systems—RQ2

Concerning blockchain technology awareness, we find highly significant differences ($p < 0.001$) in familiarity levels among consumers. The 53% (n = 159) of participants report having heard a little about blockchain technology, while 12.3% (n = 37) consider themselves experts on the technology. However, 30.7% (n = 92) have never heard about blockchain technology, and 4% (n = 12) remain unsure. These findings suggest that while blockchain awareness exists among many consumers (65.3%, n = 196), ample knowledge gaps persist.

Also, significant differences ($p < 0.001$) appear in consumer willingness to pay for blockchain-based traceability systems. The 16.7% (n = 50) of participants express definite interest in paying extra for such systems, while 40% (n = 120) respond "maybe," indicating conditional willingness. However, 39.7% (n = 119) report no interest in paying additional amounts, and 3.7% (n = 11) remain unsure. These results hint that while 56.7% (n = 170) show some level of willingness (interested or maybe), nearly equal proportions demonstrate resistance to additional costs.

Regarding payment amounts, we recognize highly significant differences ($p < 0.001$) in consumer preferences. Among those willing to pay, 28.3% (n = 85) would pay less than 5 CHF, 15% (n = 45) between 5 and 10 CHF, and 8.3% (n = 25) more than 10 CHF. However, 35.3% (n = 106) state they would not pay any amount, and 13% (n = 39) remain unsure.

Consumer interest in tipping farmers directly through blockchain-based systems exhibits highly significant differences ($p < 0.001$): 20.3% (n = 61) express definite interest in tipping farmers, while 38.7% (n = 116) respond "maybe". However, 33.7% (n = 101) report no interest in this mechanism, and 7.3% (n = 22) remain unsure. These findings suggest that the combined 59% (n = 177) express some level of interest in direct farmer support, exceeding the 56.7% who show intention to pay for traceability information. This is a modest gap that implies the social-value framing (supporting farmers) may resonate somewhat more strongly with consumers than the informational framing (accessing traceability data).

Concerning tipping amounts, highly significant differences ($p < 0.001$) are detected in consumer preferences: 30.7% ($n = 92$) of participants would tip less than 5 CHF, 22% ($n = 66$) between 5 and 10 CHF, and 5.3% ($n = 16$) more than 10 CHF. However, 27% ($n = 81$) state they would not tip, and 15% ($n = 45$) remain unsure.

4.2.3. Bivariate Analysis for Consumers

Given the relevance of Swiss consumers' desire for information about coffee provenance, we conduct a bivariate analysis to understand the characteristics of those seeking such information. For this analysis, we combine the response options "Yes" and "I am already getting this information" as "Yes", and the options "No" and "I think it is not necessary" as "No". Table 6 presents the results (% calculated on all participants, $n = 300$).

Table 6. Bivariate analysis of the characteristics of Swiss consumers who would like to know information about the provenance of the coffee.

Questions (Single-Response)		Would You Like to Know Information About the Provenance of Your Coffee? Swiss Consumers			*p*-Value **	Cramer's V (95% CI)
		Yes (*n*= 208) *n* (%)	No (*n*= 79) *n* (%)	Unsure (*n*= 13) *n* (%)		
Are you female or male?	Female	105 (35)	39 (13)	10 (3.3)	0.150 **	-
	Male	103 (34.3)	40 (13.3)	3 (1)		
	Prefer not to say	0 (0)	0 (0)	0 (0)		
What is your age?	Less than 25	36 (12)	14 (4.7)	2 (0.7)	0.427 **	-
	Between 25 and 50	112 (37.3)	34 (11.3)	8 (2.7)		
	More than 50	60 (20)	31 (10.3)	3 (1)		
	Prefer not to say	0 (0)	0 (0)	0 (0)		
How do you think you can get this information today?	Certificated labels on your coffee	74 (24.7)	17 (5.7)	4 (1.3)	0.004 **	0.188 (0.12–0.30)
	Reports from coffee-selling companies	24 (8)	6 (2)	0 (0)		
	Searching online	95 (31.7)	44 (14.7)	4 (1.3)		
	Unsure	15 (5)	12 (4)	5 (1.7)		
How would you rate the current level of trust in the information about the provenance of the coffee you are drinking and its journey to your hand?	Very low	20 (6.7)	4 (1.3)	0 (0)	0.191 **	-
	Low	40 (13.3)	13 (4.3)	2 (0.7)		
	Moderate	95 (31.7)	44 (14.7)	7 (2.3)		
	High	41 (13.7)	11 (3.7)	2 (0.7)		
	Very high	8 (2.7)	2 (0.7)	0 (0)		
	Unsure	4 (1.3)	5 (1.7)	2 (0.7)		
Have you heard about blockchain technology?	Yes, but a little bit	122 (40.7)	30 (10)	7 (2.3)	0.023 **	0.149 (0.11–0.25)
	Yes, I consider myself an expert on it	25 (8.3)	12 (4)	0 (0)		
	No, I have never heard about it	53 (17.7)	34 (11.3)	5 (1.7)		
	Unsure	8 (2.7)	3 (1)	1 (0.3)		
Would you be willing to pay extra money to get information about the provenance of the coffee you are drinking and its journey to your hand through a transparent, verifiable, and reliable system?	Yes, I am interested	47 (15.7)	3 (1)	0 (0)	<0.001 **	0.233 (0.18–0.32)
	Maybe	90 (30)	25 (8.3)	5 (1.7)		
	No, I am not interested	63 (21)	49 (16.3)	7 (2.3)		
	Unsure	8 (2.7)	2 (0.7)	1 (0.3)		
How much are you willing to pay to get information about the provenance of the coffee you are drinking and its journey to your hand through a transparent, verifiable, and reliable system?	Less than 5 CHF	71 (23.7)	12 (4)	2 (0.7)	0.002 **	0.199 (0.16–0.29)
	Between 5 and 10 CHF	34 (11.3)	10 (3.3)	1 (0.3)		
	More than 10 CHF	18 (6)	7 (2.3)	0 (0)		
	Unsure	28 (9.3)	8 (2.7)	3 (1)		
	I would not pay	57 (19)	42 (14)	7 (2.3)		
Would you like to send a tip directly to the farmer of the coffee you are drinking through a transparent, verifiable, and reliable system?	Yes, I am interested	52 (17.3)	8 (2.7)	1 (0.3)	0.007 **	0.169 (0.12–0.26)
	Maybe	85 (28.3)	25 (8.3)	6 (2)		
	No, I am not interested	59 (19.7)	37 (12.3)	5 (1.7)		
	Unsure	12 (4)	9 (3)	1 (0.3)		
How much would you like to tip the farmer for your coffee through a transparent, verifiable, and reliable system?	Less than 5 CHF	74 (24.7)	17 (5.7)	1 (0.3)	<0.001 **	0.241 (0.19–0.33)
	Between 5 and 10 CHF	50 (16.7)	14 (4.7)	2 (0.7)		
	More than 10 CHF	16 (5.3)	0 (0)	0 (0)		
	Unsure	30 (10)	13 (4.3)	2 (0.7)		
	I would not tip	38 (12.7)	35 (11.7)	8 (2.7)		

Note (%): all percentages in the table are calculated based on the total number of participants (denominator is N = 300). ** *p*-value calculated by likelihood ratio. Cramer's V: between 0 and 0.09: no association; 0.10 and 0.30: low association; 0.31 and 0.50: moderate association; and >0.50: strong association. CHF = Confoederatio Helvetica Franc.

The bivariate analysis shows significant associations between consumers interested in coffee provenance information (n = 208) and:

- Blockchain awareness (p = 0.023), with 40.7% (n = 122) mentioning that they have heard about blockchain a little bit, and 8.3% (n = 25) consider themselves experts.
- Preferred information access methods (p = 0.004), with online searching being predominant among interested consumers at 31.7% (n = 95).
- Willingness to pay ($p < 0.001$), with 15.7% (n = 47) expressing definite willingness to pay, and 30% (n = 90) replying maybe. Conversely, among consumers not interested in provenance, only 1% (n = 3) show willingness to pay, while 8.3% (n = 25) say maybe.
- Payment amounts (p = 0.002), with interested consumers demonstrating a higher willingness for all payment categories than those not interested in the information.
- Tipping willingness (p = 0.007), with 17.3% (n = 52) stating definite interest in tipping, and 28.3% (n = 85) replying maybe. In contrast, among those not interested in provenance, only 2.7% (n = 8) show strong interest in tipping, and 8.3% (n = 25) say maybe.
- Tipping amounts ($p < 0.001$), with interested consumers willing to tip more.

5. Discussion

The current research presents stakeholder perceptions regarding blockchain technology implementation for coffee supply chain traceability. An important interpretive consideration is that the data capture what stakeholders *expect*, *perceive*, and *state they intend* regarding blockchain adoption, not what blockchain technology delivers upon implementation, how consumers behave when facing real purchasing decisions, or how adoption unfolds over time. The well-documented gap between stated intentions and actual behavior [16,54,55] means that the findings presented below should be understood as perceptual patterns that inform adoption strategies rather than as confirmed outcomes of blockchain implementation. With this caveat in mind, the following sections discuss the findings in relation to existing literature, examine the practical implications, identify the study's limitations, and suggest directions for future research.

5.1. Stakeholder Perceptions of Traceability and Blockchain Technology (RQ1 and RQ2)

This study reveals significant differences in how stakeholders across geographic contexts perceive the importance of traceability and blockchain technology adoption. The finding that 78.3% of surveyed stakeholders consider traceability either very important or essential aligns with research that emphasizes traceability as fundamental to supply chain transparency and consumer confidence [16,40]. However, the moderate level of stakeholder trust (63.3%) in current information sharing indicates ongoing difficulties in achieving value chain transparency, due to insufficient communication and knowledge exchange among stakeholders, according to brewing sustainability research [54].

The limited familiarity with blockchain among coffee industry stakeholders (46.7% are not familiar at all) contrasts with consumer awareness, where 65.3% have at least some knowledge of the technology. Likewise, the existing gap in winery adoption levels reflects a similar readiness issue faced by Italian winemakers [12]. The Ethiopian coffee supply chain case shows that digital traceability technologies enhance supply chain management at the bottom level, but their adoption remains limited due to high costs, insufficient knowledge, and poor infrastructure [41], which aligns with the results of this research.

5.2. Expected Benefits and Perceived Drawbacks (RQ3)

The research data indicate that blockchain implementation is expected to yield three essential benefits: 91.7% transparency, 88.3% fraud prevention, and 86.7% security improve-

ment. The identified benefit expectations are consistent with consumer willingness-to-pay studies reporting that 68% of surveyed coffee drinkers are willing to pay extra for blockchain-based origin verification [16]. For instance, the Peruvian organic coffee cooperative case demonstrates these benefits through blockchain technology, which enables small-scale farmers to gain improved market access and more transparent payment systems [40]. However, both our findings and those of Crowley [16] reflect stated willingness rather than observed purchasing behavior, and research on the attitude-behavior gap cautions that actual payment behavior may diverge from survey-based intentions [54,55].

The universal concern about high implementation costs (reported by 95% of stakeholders) suggests that agricultural supply chains face similar adoption obstacles, a point previously studied by researchers. Research on sustainable cocoa supply chains shows that cost-related barriers share similar characteristics, as stakeholders face multiple challenges when implementing sustainability initiatives [55]. The Ethiopian study on sustainable supply chain management confirms that high financial costs, lack of top management commitment, and difficulties in assessing sustainability performance constitute critical operational barriers at the firm level [56].

The differing opinions among Colombian and Swiss stakeholders about the benefits and drawbacks of technology demonstrate that local economic conditions and geographical settings shape how people view new technologies. The Swiss stakeholders require better data management systems at a rate of 50% compared with 10% for Colombian stakeholders, while showing 66.7% concern about data privacy compared with 20% for Colombian stakeholders. According to these results, developed-market participants prioritize different operational dimensions than producing-country stakeholders.

5.3. Operational and Business Dimensions (RQ4)

The research develops a framework by evaluating blockchain's effects on nine organizational business and operational dimensions. The cost dimension is the most important factor, as stakeholders focus on implementation expenses, while fraud prevention offers substantial financial protection. This tension between investment and value creation shows that successful adoption requires alignment among organizational capabilities, supply chain characteristics, and technology settings [57].

The transparency and information dimension demonstrates the highest consensus (91.7%) regarding blockchain benefits, yet simultaneous concerns about limited expertise (91.7%) and data privacy (43.3%) reveal inherent tensions between openness and confidentiality requirements. Research on digital traceability capabilities confirms these paradoxes, noting that while traceability technologies improve information flow, they also introduce challenges related to data ownership, access rights, and the protection of competitive intelligence [41].

The cooperation and collaboration dimension highlights systemic challenges that require industry-wide solutions. The finding that 81.7% of stakeholders identify government support as necessary, while 93.3% recognize a lack of awareness as a primary barrier, echoes research on the Swedish–Vietnamese coffee value chain, which emphasizes that insufficient communication among stakeholders creates knowledge gaps that prevent collaborative sustainability initiatives [54]. The study argues that individual perceptions are constructed through both internal features and external circumstances, which differ substantially along global value chains and need communication platforms to reach common ground.

5.4. Consumer Perspectives on Blockchain Traceability

The consumer findings reveal nuanced attitudes toward blockchain-based traceability systems. While 62.7% express interest in provenance information, only 16.7% are willing to

pay for blockchain-verified systems, with 39.7% unwilling to incur additional costs. These results partially align with international consumer studies showing that younger, male, tertiary-educated, high-income, heavy coffee drinkers exhibit a higher willingness to pay (approximately €0.38, or a 15% premium) for blockchain traceability [16].

The higher stated consumer willingness to tip farmers directly (59% showing some interest) compared with their willingness to pay for information systems (56.7%) suggests that, at the level of expressed preferences, consumers may prioritize social impact over improvements in transactional transparency. This finding supports research demonstrating that consumers increasingly value ethical production and direct farmer support. However, stated willingness may not fully predict actual behavior, as research consistently demonstrates a gap between reported sustainability attitudes and observed purchasing decisions [16,54,55].

The bivariate analysis confirms significant associations ($p < 0.001$) between provenance interest and both stated willingness to pay and tipping amounts, suggesting that targeted education about coffee origins and production conditions could enhance blockchain adoption by leveraging existing consumer interest.

5.5. Barriers to Blockchain Adoption

This study identifies implementation barriers operating at multiple levels: technological (complexity, interoperability), organizational (limited understanding, staff capabilities), and institutional (regulatory frameworks, standardization). These multilevel barriers align with literature identifying technological infrastructure challenges, data governance issues, high initial investments, and stakeholder resistance as persistent obstacles to blockchain adoption in coffee supply chains [8]. The Ethiopian coffee industry research similarly categorizes barriers as drivers, enablers, and barriers, demonstrating that successful implementation of sustainable supply chain management requires addressing internal organizational factors, supply chain relationships, and external institutional frameworks simultaneously [56].

The significant barrier of limited understanding and expertise (91.7%) among surveyed stakeholders suggests fundamental knowledge gaps requiring comprehensive educational interventions. Research on blockchain adoption in family-owned Italian wineries demonstrates that traditional business structures characterized by personal relationships and established trust mechanisms may resist technological solutions perceived as depersonalizing or threatening existing relationship networks [12]. However, the same research indicates that digital technologies, particularly blockchain, can complement rather than replace traditional trust mechanisms when properly implemented with stakeholder consultation and gradual integration strategies.

Research on cocoa supply chain barriers provides valuable parallels, identifying complexity, traceability challenges, power dynamics, and overreliance on certification as primary obstacles [55]. The study emphasizes that retailers exhibit positive attitudes toward sustainability but need support to overcome systemic barriers, a finding directly applicable to coffee supply chain stakeholders who recognize blockchain's potential (43.3% see competitive advantages) yet face implementation obstacles. The recommendation for "certification plus" strategies, combining third-party verification with company-specific blockchain policies, offers a practical pathway for coffee industry stakeholders to incrementally adopt transparency technologies while maintaining certification credibility.

5.6. Interpretation of Findings Through the Lens of the UTAUT Framework

The UTAUT framework provides a theoretical lens for understanding the adoption dynamics observed in the present study. We use UTAUT only as an interpretive lens for

the findings. This section interprets the empirical findings through the four core UTAUT constructs: performance expectancy, effort expectancy, social influence, and facilitating conditions; and examines the role of moderating variables.

- Performance expectancy (PE). Performance expectancy reflects the extent to which stakeholders believe blockchain technology will help them achieve operational and business gains [17]. The results indicate strong perceptions of performance expectancy. The three primary benefits, improved transparency (91.7%), fraud prevention (88.3%), and enhanced security (86.7%), reflect a robust belief that blockchain can deliver substantial supply chain improvements, corresponding directly to the performance gains that UTAUT identifies as the strongest predictor of adoption intention [17,18]. The classification of expected outcomes across operational dimensions further reinforces this construct: cost reduction emerges as the predominant objective (53.3%), followed by sales increase (48.3%), and 43.3% of surveyed stakeholders perceive blockchain as a potential competitive advantage. These findings are consistent with prior studies. Rogerson and Parry [29] report that performance expectancy exhibits the strongest statistical correlation with blockchain usage behavior ($\beta = 0.755$), while Bentivoglio et al. [12] find it is the most significant predictor among Italian winemakers ($\beta = 0.738$, $p < 0.001$). However, the geographic differences in benefit expectations, Colombian stakeholders prioritize cost reduction (63.3%) and fraud prevention (90%), while Swiss stakeholders emphasize data management (50%) and ethical practices (56.7%), suggesting that performance expectancy is context-dependent, consistent with Venkatesh et al.'s [17] recommendation that UTAUT should be conceptualized within specific contexts.
- Effort expectancy (EE). Effort expectancy reflects the perceived ease or difficulty associated with using blockchain technology [17]. The findings show that effort expectancy represents a critical barrier. A total of 91.7% of surveyed stakeholders report limited understanding and expertise, 86.7% identify technical complexity as a barrier, and 46.7% describe themselves as completely unfamiliar with blockchain technology. The current technology landscape amplifies these concerns: all participants still rely on paper forms, digital database usage varies between Colombia (63.4%) and Switzerland (100%), and no stakeholders currently use blockchain, IoT, or AI for traceability. Investment intention further reflects effort-related concerns: 40% are unwilling to invest at all, and 48.3% accept only low investment. These findings align with Surarityothin et al. [11], who report that older users find blockchain unacceptable due to lower digital readiness, and with Tadesse et al. [41], who confirm that adoption of digital traceability in Ethiopia remains limited due to insufficient knowledge and poor infrastructure. However, the results contrast with Bentivoglio et al. [12], who find effort expectancy nonsignificant among Italian winemakers, suggesting that in more digitally mature contexts, effort barriers may be less determinative.
- Social influence (SI). Social influence captures the degree to which stakeholders perceive that important others expect them to adopt blockchain technology [17]. The geographic differences between Colombian and Swiss stakeholders constitute one of the most consistent findings, with highly significant differences ($p < 0.001$) in blockchain familiarity, benefit expectations, and willingness to invest. Swiss stakeholders demonstrate higher familiarity (73.3% somewhat familiar or familiar vs. 33.3% in Colombia) and greater confidence in future adoption (86.7% vs. 66.7%), suggesting that the social and institutional environment shapes perceptions of technology. Consumer demand represents another dimension of social influence: 62.7% of surveyed consumers express interest in provenance information, 95% of studied companies expect consumer traceability requests to increase, and 59% of sample consumers show

interest in tipping farmers directly. These preferences create market-driven social pressure toward blockchain adoption. The finding that 48.3% of surveyed stakeholders identify industry-wide collaboration as necessary further reflects the multi-stakeholder nature of adoption decisions. Kessler and Tokle [54] emphasize that insufficient communication between stakeholders creates knowledge gaps, preventing collaborative initiatives, a dynamic directly related to social influence.

- Facilitating conditions (FC). Facilitating conditions reflect stakeholders' beliefs about the availability of organizational and technical infrastructure to support blockchain use [17]. This construct receives the most extensive empirical support and emerges as perhaps the most critical factor explaining the current adoption gap among the study's participants. Training and education programs are identified as the most critical resource by 93.3% of surveyed stakeholders, followed by financial incentives (86.7%), technical expertise (85%), and government support and regulations (81.7%). The finding that 80% of participant companies neither use nor plan to implement blockchain, while only 13.3% plan to adopt it in the future, further illustrates a deficit in facilitating conditions. The need for government support (81.7%) indicates that surveyed stakeholders view blockchain adoption as requiring institutional frameworks and regulatory clarity, rather than relying solely on market forces. Kramer et al. [13] similarly emphasize that facilitating conditions in coffee supply chains include limited internet access in rural areas and the requirement for customized training. The Peruvian cooperative case by Fernández [40] demonstrates that stakeholder consultation and participatory design significantly improve the feasibility of adoption, suggesting that targeted investment in facilitating conditions can bridge the gap between performance expectations and actual adoption.
- Among the participants in the study, the geographic context functions as the most prominent moderating variable, producing significant differences ($p < 0.001$) across nearly all dimensions. This moderation reflects structural differences in digital infrastructure, regulatory environments, and market sophistication. Professional experience shows significant differences between groups ($p = 0.043$), with Swiss stakeholders having more experience overall. In the consumer survey, age distribution (51.3% aged 25–50, 31.3% over 50) and gender (51.3% female, 48.7% male) provide the demographic variation that UTAUT moderators are designed to capture. Surarityothin et al. [11] confirm the relevance of age moderation, finding that stakeholders over 45 years show lower acceptance.

In synthesis, the UTAUT framework interpretation suggests a characteristic early-stage adoption pattern: strong performance expectancy coexists with constraining conditions across the other three constructs. Participants clearly recognize the potential benefits of blockchain for transparency, fraud prevention, and security, yet these expectations are insufficient to drive adoption without adequate effort expectancy (limited knowledge, technical complexity), social influence (uneven cross-geographic dynamics, emerging but incomplete consumer pressure), and facilitating conditions (critical gaps in training, funding, expertise, and regulatory support). This pattern, high PE combined with constrained EE, SI, and FC, is consistent with early-stage adoption dynamics described by Venkatesh et al. [17–19] and confirmed by blockchain studies in agri-food contexts [8,12,13].

Based on the observed perceptual patterns, the findings suggest that successful adoption would likely require simultaneous investment in reducing perceived effort barriers through education, strengthening social influence through industry collaboration and consumer engagement, and building facilitating conditions through financial support, technical infrastructure, and regulatory frameworks. Confirming these adoption dynamics

requires longitudinal studies tracking the relationship between interventions and actual adoption behavior over time.

5.7. Practical Implications

According to the findings from the surveyed stakeholders, this research offers several practical implications for the coffee industry, technology providers, and policymakers. First, participants' recognition of the importance of traceability, combined with moderate current trust levels (48.7%), suggests real opportunities for blockchain solutions to address transparency gaps. However, the dominant cost concerns (95%) suggest that implementation strategies should emphasize return on investment through fraud reduction, operational efficiency gains, and market access improvements, rather than positioning blockchain solely as a compliance or ethical enhancement.

Second, substantial knowledge gaps regarding blockchain technology (46.7% of surveyed companies are completely unfamiliar with it) require comprehensive educational programs before widespread adoption becomes feasible. The finding that training and education programs represent the most critical resource need (93.3%) suggests that industry associations, government agencies, and technology providers should prioritize capacity building through workshops, demonstration projects, and peer learning networks. The Peruvian cooperative case demonstrates that stakeholder consultation and participatory design processes significantly improve system feasibility and adoption rates [40].

Third, the geographic differences between Colombian and Swiss stakeholders regarding benefit expectations and drawback concerns suggest that blockchain implementation strategies require context-specific customization rather than universal approaches. Producing-country stakeholders prioritize cost reduction and fraud prevention, while consuming-country participants emphasize data management and privacy protection. Technology providers should develop modular, scalable solutions that allow stakeholders to implement core functionality tailored to their operational priorities and resource constraints.

Fourth, surveyed consumer findings suggest that blockchain adoption should emphasize social impact dimensions (direct farmer support) alongside transparency improvements to maximize market acceptance. The higher willingness to tip farmers, 59% of participants showing interest, than to pay for traceability information (56.7%) suggests that blockchain platforms integrating direct payment mechanisms for producers may achieve stronger consumer engagement than pure information systems.

5.8. Study Limitations

This study acknowledges several limitations that affect the generalizability of the results and their interpretation. First, it employs a non-probabilistic convenience sampling strategy with relatively small per-cluster company subgroups (six participants per Colombian stakeholder cluster and ten per Swiss company cluster), which limits both the statistical power for inferential comparisons at the individual cluster level and the generalizability of the findings to other coffee-producing and -consuming regions. While these subgroup sizes are consistent with comparable exploratory studies in the blockchain adoption literature [4,6,12,16], the findings from the company survey should be interpreted as indicative of perception patterns within the studied populations rather than as representative of the coffee supply chain as a whole. The purposive selection of the Department of Huila (Colombia) and the Canton of Vaud (Switzerland) enables meaningful cross-context comparison but reflects specific institutional environments, infrastructure capabilities, and market structures that may differ substantially from other producing countries (e.g., Ethiopia, Vietnam, Brazil) and consuming markets (e.g., North America, Asia). Future

research should expand geographic coverage and employ probability-based sampling approaches with larger per-cluster sizes to enhance statistical power and generalizability.

Second, the cross-sectional research design captures stakeholder perceptions at a single point in time, preventing analysis of how attitudes and adoption intentions evolve as blockchain technology matures and implementation examples emerge. Longitudinal research tracking stakeholder perceptions across multiple years would provide valuable insights into adoption readiness, development, and technology diffusion patterns.

Third, the analysis focuses exclusively on blockchain technology for traceability, rather than on alternative or complementary digital solutions (IoT sensors, artificial intelligence, mobile applications) that may offer comparable or complementary functionality in specific use cases. Future research should adopt comparative technology assessment approaches examining blockchain alongside alternative digital traceability solutions to identify optimal technology combinations for different supply chain contexts.

Fourth, this research captures stakeholder perceptions and stated intentions at a single point in time, and the findings should not be interpreted as evidence of actual blockchain implementation outcomes, observed purchasing behavior, or confirmed adoption trajectories. The well-documented gap between stated intentions and actual behavior, particularly regarding willingness to pay for sustainability-related attributes [16,54,55], means that the sales, market performance, and consumer behavior implications discussed in this article represent anticipated outcomes based on stakeholder expectations rather than empirically confirmed effects. It is necessary to conduct future research employing experimental designs, field experiments, or longitudinal tracking of actual implementation projects to determine whether and to what extent the perceived benefits and drawbacks identified in this work correspond to real-world outcomes.

5.9. Recommendations for Future Research

This study identifies several promising avenues for future investigation. First, pilot implementation studies examining real-world blockchain deployments in coffee supply chains would provide empirical evidence on actual costs, operational impacts, and stakeholder adoption patterns, thereby addressing the gap between theoretical benefits and practical realization. Such research should employ action research methodologies, enabling researchers to collaborate with industry actors throughout implementation.

Second, comparative studies examining blockchain adoption across different agricultural commodities (coffee, cocoa, wine, organic products) would illuminate sector-specific factors influencing technology acceptance and identify transferable best practices. The finding that similar barriers emerge across coffee and cocoa supply chains [55] suggests potential for cross-sector learning and technology standardization.

Third, research investigating the integration of blockchain with complementary technologies (IoT, AI, mobile platforms) would address the limitations of standalone blockchain solutions and identify synergistic technology combinations that optimize traceability system performance. The Ethiopian case demonstrates that fully digitized traceability systems that combine multiple technologies can overcome the limitations of individual technologies [41].

Finally, research exploring business model innovations that enable economically sustainable blockchain implementation would address the dominant cost barrier (cited by 95% of participants). This could include examining consortium-based cost-sharing arrangements, hybrid public–private blockchain architectures, and value-added service models that generate revenue streams to offset implementation expenses.

6. Conclusions

Among the surveyed stakeholders in the coffee supply chain, 78.3% rate traceability as essential or very important, and they identify three main perceived benefits of blockchain: improved transparency (91.7%), fraud prevention (88.3%), and enhanced security (86.7%). However, substantial perceived barriers persist: 95% of participants cite high implementation costs, 91.7% limited knowledge and skills, and 93.3% inadequate awareness as key obstacles; all of which require joint solutions from technology developers, industry actors, and policymakers. The classification of these perceived benefits and drawbacks, across nine operational and business dimensions, illustrates how expected blockchain effects vary across stakeholder groups and geographic contexts: Colombian participants prioritize cost reduction and fraud prevention, while Swiss stakeholders emphasize data management and privacy protection.

The interpretation of the findings through the lens of the UTAUT framework suggests that while performance expectancy is strong, participants recognize the perceived potential of blockchain to improve supply chain operations; adoption appears constrained by low effort expectancy due to limited knowledge and technical complexity, uneven social influence across geographic contexts, and insufficient facilitating conditions in terms of training, funding, technical expertise, and regulatory support. This pattern is consistent with early-stage technology adoption dynamics and indicates that overcoming the current adoption gap requires simultaneous interventions across all four UTAUT constructs, not merely demonstrations of blockchain benefits.

Based on these exploratory findings, blockchain adoption requires context-specific implementation strategies rather than universal approaches, the creation of educational programs to fill knowledge gaps, and policy frameworks to facilitate the technology integration. The research shows that surveyed consumers express greater stated interest in direct farmer tipping (59%) than in paying for traceability information systems (56.7%), suggesting that blockchain platforms linking social value to transparency enhancements may find stronger market receptivity. However, whether stated preferences translate into actual market performance requires validation through pilot implementation and behavioral observation studies.

Also, the results from the surveyed stakeholders suggest that the technology solutions should be developed as separate modules to meet the requirements of various stakeholders, and that the government should establish regulatory guidelines and economic incentives to support blockchain initiatives. Finally, surveyed consumers expect blockchain implementation in the coffee supply chain to focus more on ethical farming practices and proper farmer compensation than on proving technical capabilities for traceability.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/technologies14060369/s1, Supplementary Materials File S1: Instruments to collect data and their face and content validity; Supplementary Materials File S2: Results of perception about traceability and the use of blockchain technology.

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