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| RESEARCH ARTICLE

Exploring the Role of Blockchain Technology in Enhancing Product Quality Perception and Purchase Behavior in Cross-Border E-Commerce Cosmetics

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| ABSTRACT
This study investigates how blockchain-based supply chain traceability influences consumer behavior in the context of CBEC cosmetics. Drawing on signaling theory, we examine whether traceability information enhances consumers' purchase intentions and whether perceived product quality mediates this relationship. We conducted a between-subjects online experiment involving 219 Chinese consumers, comparing responses to a cosmetics product page with and without blockchain-enabled traceability information. Results from ANOVA and PROCESS Model 4 analysis reveal that traceability information significantly increases purchase intention, and this effect is fully mediated by perceived product quality. These findings extend the application of signaling theory to digital transparency tools and offer practical implications for CBEC platforms and brand managers seeking to combat counterfeiting and improve consumer trust. By confirming the psychological signaling role of blockchain, this study contributes to the broader understanding of how emerging technologies shape consumer perceptions and behavior in high-risk product categories.

| KEYWORDS
Blockchain, CBEC, Cosmetics, Traceability, Purchase Intention, Perceived Product Quality, Signaling Theory

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1. Introduction

In recent years, cross-border e-commerce (CBEC) in China has experienced rapid growth, with particularly strong performance in the cosmetics sector. According to the data, the sales volume of this category increased by 14.24% from 2021 to 2022. Chinese consumers prefer to purchase international cosmetic brands through CBEC platforms primarily due to greater convenience and price advantages compared to domestic counters. However, the high-profit margins in the cosmetics market continue to drive the proliferation of counterfeit products, which remain difficult to eradicate even on major platforms. This risk is especially pronounced in CBEC settings, where consumers cannot physically inspect products and must rely solely on limited information provided online, exacerbating issues of information asymmetry and trust deficiency (Mavlanova et al., 2012). Previous research has demonstrated that such information asymmetry not only undermines customer trust but also has a major impact on purchase intention. (Ikhsan et al., 2024). For cosmetics—products with high demands for authenticity and safety—the lack of transparency in information has raised considerable concern. To address the challenges, researchers have begun to explore blockchain-based traceability technologies. A key advantage of blockchain lies in its ability to establish immutable data recording systems, which enhances both the transparency and verifiability of product information，thus strengthening consumer trust in product quality(Hussain et al., 2024).

Currently, blockchain has been widely applied in areas such as food safety and agricultural logistics (Vignesh et al., 2025). It is regarded as an effective tool for improving supply chain transparency and operational (Wang et al., 2021). Nevertheless, existing research still predominantly focuses on technical dimensions—such as system architecture and feasibility assessment(Bosona &

Gebresenbet, 2023; Dasaklis et al., 2022). Relatively few studies have actively explored how blockchain influences consumer behavior in the context of consumer goods, especially on CBEC platforms. Maesano et al.(2025) noted that consumers' understanding of blockchain's potential benefits remains limited, especially regarding the mechanisms by which traceability information affects their purchasing intentions. Although prior research has separately examined the impact of blockchain labels on consumer purchase intentions in traditional offline context(Treiblmaier & Garaus, 2023) , as well as the effect of supply chain traceability on consumer attitudes in the CBEC food sector (Ying et al., 2023) ,there is still a lack of systematic, mechanism-oriented studies on how traceability information functions as a signaling mechanism to influence consumer decision-making in CBEC platforms—particularly in the cosmetics sector, where authenticity and quality concerns are especially salient.

Given the aforesaid research gap, this project aims to answer the following questions :

(1) Can blockchain supply chain info (BSCI) significantly enhance consumers' purchase intentions for cosmetics on CBEC platforms?

(2) Does perceived product quality serve as a mediating factor in this relationship?

To address the above questions, this study adopts signaling theory as the theoretical foundation and employs a between-subjects experimental design. By manipulating the presentation of supply chain information received by the experimental and control groups, the study examines the underlying mechanisms. We collected data using a structured questionnaire and tested the mediating effect of perceived product quality with PROCESS Model 4 in SPSS.

This study makes three key contributions : First, it extends the application of blockchain technology in consumer behavior research by highlighting its potential as a signaling mechanism. Second, it fills a research gap by investigating the impact mechanism of traceable supply chain information on consumers in the context of CBEC cosmetics. Third, it provides practical managerial implications for platforms and brand owners regarding the presentation of supply chain information. The paper is organised as follows. Section 2 provides a literature review, summarizing current research on blockchain technology, supply chain information, and consumer behavior. Section 3 develops the research hypotheses and constructs the conceptual framework based on signaling theory. Section 4 discusses the research methods and empirical findings, which include experimental design, data gathering, and statistical analysis. Section 5 delves into the important discoveries and their theoretical and practical ramifications. Section 6 closes the report by providing managerial insights and outlining future research topics.

2 Review of the Literature

2. 1 ***Signal theory***

Signal theory, founded on information economics, discusses how market actors reduce information asymmetry by providing observable and trustworthy signals to convey otherwise unobservable features (Brouthers et al., 2008; Connelly et al., 2011). Marketing and consumer behaviour scholars have actively applied this theory to examine how firms communicate product quality and credibility under uncertain conditions. Firms use signals to mitigate the adverse effects of country-of-origin bias (Brouthers et al., 2008), reinforce quality perceptions through umbrella branding strategies (Erdem, 1998), and shape consumer attitudes in green marketing contexts (Berger, 2019; Schena et al., 2015).

When consumers cannot easily verify key product attributes—such as safety, quality, or ethical sourcing—before making a purchase, firms actively deploy observable signals, including product warranties, third-party certifications, and traceability information, to reduce perceived risk (Boulding & Kirmani, 1993; Przepiorka & Berger, 2017). Unlike passive informational cues, firms intentionally transmit these signals to highlight their reliability and demonstrate their commitment to quality (Koku, 2014).

Recent studies have actively integrated signal theory into research on supply chain transparency. Scholars have identified traceability systems as practical signaling tools that allow firms to reduce uncertainty by making supply chain information visible,verifiable, and consistent. By using these systems, firms enhance consumers' perceptions of product quality and increase their willingness to pay (Choe et al., 2013; Tao & Chao, 2024; Treiblmaier & Garaus, 2023). These signaling effects become particularly pronounced when consumers lack brand familiarity or encounter inconsistent online reviews (Ying et al., 2023)

As digital technologies advance, researchers increasingly apply signal theory to technology-enabled contexts. Firms have begun to use blockchain as a credible signal due to its decentralization, immutability, and verifiability. By integrating blockchain into their supply chains, firms communicate product authenticity, ethical sourcing, and operational integrity to consumers (Z. Liu & Li, 2020; Rapezzi et al., 2025) Blockchain-backed information helps firms reduce information asymmetry, enhance consumer trust, and improve perceptions of environmental and ethical responsibility (Le, 2024; Wang et al., 2021).

Despite these developments, researchers continue to identify key gaps in the literature. Studies have shown that the effectiveness of signals depends on product type, brand familiarity, and the consistency of the message across channels (Dickey et al., 2022; Mollenkopf et al., 2022). However, few researchers have examined how firms implement transparency signals in CBEC platforms, where consumers often face heightened information asymmetry and limited product verification opportunities (Muratore & Marques, 2020). To address this, scholars recommend exploring signaling equilibrium mechanisms and integrating signal theory with complementary frameworks—such as cue utilization theory and information integration theory—to better explain how consumers make decisions under uncertainty (Bergh et al., 2014; Sodhi & Tang, 2019).

2.2 Cross-Border E-Commerce

Cross-border e-commerce (CBEC) refers to online commercial transactions between consumers and sellers in various nations or regions, which are enabled by digital platforms. This model has rapidly expanded as a segment of global trade, particularly in China, where national policies—such as the Belt and Road Initiative—and investments in digital infrastructure have fueled its growth (Zhu, 2018). CBEC platforms provide consumers with access to international brands and products at competitive prices, while enabling global sellers to enter large and rapidly expanding markets.

Despite its momentum, CBEC still presents significant operational and trust-related challenges. Geographical and regulatory gaps often prevent consumers from verifying product authenticity, understanding logistics, or resolving post-sale issues (Mu, 2022). These problems become especially acute in quality-sensitive categories, such as cosmetics. Fragmented logistics and inconsistent customs policies frequently delay deliveries, obscure shipment tracking, and undermine the overall shopping experience(Giuffrida et al., 2021).

Consumers evaluate product quality in CBEC environments based on a combination of informational cues and contextual factors. One of the most influential is the country-of-origin (COO) effect. Chinese customers tend to trust products from nations with high reputations for quality, whereas they frequently show mistrust about items marked "Made in China" in specific categories. (Bao et al., 2021). As a result, many consumers rely on the national image as a heuristic when they cannot inspect the product directly. Brand image and reputation also shape quality perception. Consumers generally view well-established international brands as more trustworthy because of their consistent performance and perceived reliability.

In online shopping environments where direct product evaluation is impossible, consumers often rely on brand reputation as a proxy for credibility (Chen, 2022). This reliance intensifies when other product information is vague or incomplete. The quality of the e-commerce platform itself also matters. Factors such as platform design, ease of navigation, and the clarity and accuracy of product descriptions significantly influence how consumers perceive product quality. A seamless and intuitive interface boosts user confidence and encourages purchase intention.

Logistics and delivery services also shape how consumers perceive product quality. When sellers ensure reliable and timely delivery, consumers often interpret it as a sign of professionalism and care (Giuffrida et al., 2021). In regulated sectors such as cosmetics and food, brands that display certifications and comply with international safety standards help consumers identify quality more confidently. Prominently displaying these credentials can build trust and reduce perceived risk (Zhao et al., 2024).

Social proof mechanisms, such as customer reviews and ratings, play a vital role when physical inspection is not possible. Positive reviews reduce uncertainty and enhance trust, whereas negative feedback discourages purchases (Bo et al., 2023). These signals empower consumers to make more informed decisions in the face of persistent information asymmetry. Although CBEC continues to democratize access to global products, concerns about trust and transparency still hinder its long-term success, especially in categories like cosmetics, where authenticity and safety remain paramount. These challenges have prompted researchers and practitioners to explore advanced technologies, such as blockchain, to address information asymmetry and rebuild consumer trust.

2.3. Blockchain Technology

At its core, blockchain operates as a decentralized and distributed ledger system, allowing multiple parties to securely and transparently record data without relying on centralized intermediaries (Paik et al., 2019; Philsoophian et al., 2021). Each block links to its predecessor through a cryptographic hash, stores timestamped transaction data, and achieves validation through consensus mechanisms such as Proof of Work or Proof of Stake (Baboi, 2023). This structure ensures data integrity, facilitates traceability, and prevents tampering.

Researchers increasingly describe blockchain as a “trust-building machine” due to several technical features that reinforce credibility (Yavaprabhas et al., 2022). First, blockchain decentralizes data storage by enabling each node in the network to independently verify and retain records, thereby enhancing system resilience and transparency (Monrat et al., 2019), Second, the system maintains immutability by requiring broad consensus before any party can alter recorded information, thereby reducing opportunities for fraudulent manipulation (Gao & Li, 2021). Third, blockchain promotes transparency by providing authorised stakeholders with access to transaction records, which fosters confidence in the authenticity and traceability of product origins (Tiscini et al., 2020). Blockchain also strengthens data security by employing cryptographic protocols that prevent unauthorized access or modification (Kumbharkar et al., 2024). Additionally, it enhances traceability by enabling real-time tracking of product movement across supply chains, which is particularly important in the cosmetics sector, where ingredient sourcing is crucial (Hasan et al., 2020). Finally, blockchain supports auditability by allowing retrospective reviews of transaction histories, which fosters operational accountability (Ahmed et al., 2022).

Within supply chain management, blockchain enhances operational efficiency and improves product visibility across all stages of the supply chain. For instance, companies in the cosmetics industry apply blockchain to authenticate ingredients, verify compliance with manufacturing standards, and demonstrate ethical sourcing practices (MacCarthy et al., 2024). By digitally linking every node in the supply chain, blockchain ensures consumers can access accurate and tamper-proof product data. This

capability not only deters counterfeiting but also supports claims about environmental and ethical sustainability (Hastig & Sodhi, 2020).

From the consumer's perspective, blockchain improves the online shopping experience in several ways. It builds trust in product authenticity and reinforces brand transparency (Sudirjo & Tjahyadi, 2023). It also enables users to identify ethically produced and allergen-sensitive goods (Amoako et al., 2020) and reduces fraud risks by decentralising transaction validation (Anwar et al., 2021). Moreover, consumers benefit from faster and more secure transactions through smart contracts and encrypted payment channels (Chen, 2022). Blockchain also delivers cost efficiencies by eliminating intermediaries and streamlining logistics (Tanuwijaya et al., 2023), while empowering consumers by granting them more control over their data (Bhatti & Rehman, 2020).

Despite its advantages, blockchain adoption continues to face challenges. As transaction volumes increase, scalability issues arise, which in turn reduce performance (Andronie et al., 2023). Public blockchains, although transparent, raise privacy concerns that sometimes conflict with regulations such as the GDPR (Kamath, 2018). Developers struggle to integrate blockchain into existing legacy systems due to technical complexity (Ahmed et al., 2022), and many fragmented supply chains lack unified data standards (MacCarthy et al., 2024). Additionally, the high cost of blockchain implementation poses a barrier for small and medium-sized enterprises . Without widely accepted interoperability standards, cross-platform collaboration remains limited ((Zhang et al., 2024).

Consumers generally perceive blockchain technology positively in the cosmetics e-commerce sector, although awareness levels significantly influence this perception. Research shows that many consumers value blockchain for combating counterfeit products and promoting ethical sourcing (Hina et al., 2024a). Transparent supply chains enhance purchase confidence, particularly among consumers who prioritise sustainability (Panghal et al., 2023). However, limited understanding of blockchain functionality and its applications within product ecosystems continues to hinder broader consumer engagement (Duong et al., 2024). These knowledge gaps underscore the need for brands to communicate clearly and educate consumers about the role of blockchain in enhancing product integrity.

Blockchain technology enables the transmission of multiple credible signals in the supply chain context. These signals—ranging from traceability and transparency to auditability and ethical certification—convey unobservable product attributes, helping consumers navigate information asymmetry in cross-border transactions. Table 1 summarises the core signal types, their underlying mechanisms, and the perceived outcomes highlighted in recent literature.

Table 1**. A Research Framework for the Classification of Product Signalling Mechanisms and Their Consumer Perception Effects**

Signal Type	Transmission Mechanism	Perceived Outcome	Source
Country-of-Origin Image	National branding, product labeling	Heuristic cue for perceived quality and authenticity	Bao et al., 2021; Brouthers et al., 2008
Brand Reputation	Past performance, global presence	Trust in quality, lower perceived risk	Chen, 2022; Erdem, 1998
Platform Characteristics	User interface, information clarity	Enhanced consumer confidence, perceived product professionalism	Giuffrida et al., 2021
Logistics Performance	Delivery speed, condition on arrival	Perceived seller reliability, quality inference	Zhao et al., 2024
Third-Party Certification	Compliance logos, safety symbols	Formal assurance of safety and credibility	Panghal et al., 2023; Zhao et al., 2024
Consumer Reviews	Rating systems, user comments	Social proof, trust reinforcement	A. Liu et al., 2021
Traceability	Blockchain tracking, digital records	Authenticity, reduced uncertainty	Hasan et al., 2020; Treiblmaier & Garaus, 2023
Transparency	Open ledgers, visible product journey	Brand credibility, trust in claims	Sudirjo & Tjahyadi, 2023; Tiscini et al., 2020
Immutability	Hash-protected records, tamper-resistance	Trust in data reliability	Gao & Li, 2021
Auditability	Access to historical logs, full transaction visibility	Regulatory compliance, consumer empowerment	Ahmed et al., 2022
Ethical Certification	Blockchain-verified ethical sourcing, fair trade labels	Support for sustainability, emotional brand connection	Hina et al., 2024a

3 Hypothesis development

Blockchain technology has garnered increasing attention from both scholars and practitioners due to its potential to enhance traceability across global supply chains. In high-risk sectors, such as food and cosmetics, where product safety, authenticity, and

origin are paramount, blockchain-enabled systems provide a reliable mechanism to reduce information asymmetry and enhance consumer trust. Theoretical frameworks—especially signalling theory—explain how traceability information functions as a strategic signal in markets where consumers cannot directly evaluate product attributes, as is often the case in CBEC. Drawing on this perspective and supported by emerging empirical findings, we propose two hypotheses that explore the relationships among blockchain-based traceability, perceived product quality, and consumer purchase intention.

3.1 The Relationship Between Blockchain Traceability Information and Purchase Intention

Blockchain technology has revolutionized supply chain transparency by enabling the real-time tracking of product origins and logistics processes. In consumer-facing industries such as food and cosmetics, companies increasingly treat traceability not just as an operational tool, but as a strategic signal of product authenticity and safety. According to signaling theory (Connelly et al., 2011; Spence, 2002), firms can use traceability information as a credible signal to bridge the information gap between buyers and sellers—particularly in CBEC, where consumers lack the opportunity for direct product inspection and must rely on digital cues to assess quality and trust.

A growing body of empirical research supports the idea that blockchain-enabled traceability boosts purchase intentions. For example, Tran et al.(2024) demonstrated that consumers were willing to pay a premium for Feta cheese verified by blockchain, reflecting the added perceived value of transparent sourcing. Likewise, Lin et al. (2020) found that 37% of Chinese consumers were willing to pay more for U.S. beef when presented with blockchain traceability. These studies suggest that consumers interpret traceability labels as indicators of quality, which in turn increases their likelihood of purchase.

Furthermore, blockchain enhances consumer trust by offering immutable and transparent information about supply chains. Duong et al. (2024) emphasized that this level of transparency provides consumers with a greater sense of security in their purchasing decisions. Similarly, Hina et al. (2024b) demonstrated that blockchain traceability enhanced perceived product quality, which in turn increased purchase intentions. Health-sensitive contexts amplify this pattern, as perceived health risks strongly motivate consumers to choose products that are traceable. For instance, Zhai et al. (2022) reported that food safety concerns led consumers to prefer blockchain-traceable fresh fruit.

Additional studies suggest that the effectiveness of traceability signals depends not only on their presence but also on consumers' understanding of their value and credibility. Li (2022) found that consumer knowledge of traceability, along with the perceived credibility of the certifying institution, influenced purchase behaviour by reducing perceived risk and enhancing perceived value. Collectively, these findings support the argument that blockchain-based traceability serves as a powerful indicator of quality and safety in high-risk and cross-border purchasing scenarios.

Therefore, we propose the following hypothesis**:**

H1 : Blockchain-based traceability information positively influences consumers' purchase intentions in CBEC.

3.2 The Mediating Function of Perceptions of Product Quality

In traceability-driven contexts, the perceived quality of a product plays a pivotal role in shaping consumer purchase intentions. As transparency emerges as a central concern—particularly in sectors such as food and cosmetics—consumers increasingly use traceability mechanisms to assess product credibility. These mechanisms, often supported by technologies like blockchain, not only inform consumers about product provenance and safety but also signal superior quality.

Recent studies have revealed a strong link between traceability and increased perceptions of product quality. For example, Duong et al. (2024) found that consumer trust in blockchain-enabled transparency mediates the relationship between traceability and purchase intention, suggesting that traceable information enhances perceived quality, which in turn increases consumers' willingness to buy. Similarly, Sander et al. (2018) observed that traceability systems in meat supply chains improved consumers' perceptions of quality and positively shaped their purchase decisions.

Several scholars have also emphasised the importance of consumer knowledge in this process. Lin et al. (2023) showed that consumers with higher levels of traceability knowledge tend to perceive products as higher in quality, which directly affects their intention to purchase. Yuan et al. (2020)further highlighted the influence of perceived value—primarily shaped by quality perceptions—as a key determinant of purchasing behaviour in traceable product contexts.

Li (2022) demonstrated that traceability knowledge influences purchase decisions through two cognitive mediators: perceived risk and perceived value, with the latter closely linked to quality perceptions. This finding reinforces the argument that consumers often interpret traceable product attributes through the lens of perceived quality.

Building on this, Chiu et al. (2023) found that perceived product quality interacts with health and safety concerns to influence purchase intentions, underscoring its central mediating function. Consistent with this perspective, Rijswijk and Frewer (Rijswijk & Frewer, 2008) argued that consumers commonly treat product quality and safety as interconnected constructs, using traceability as the unifying signal.

Taken together, these findings affirm the mediating role of perceived product quality in the relationship between blockchain-based traceability and consumer purchase intentions.

Therefore, we propose:

H2 **:** Perceived product quality mediates the relationship between blockchain-based traceability and consumers' purchase intentions.

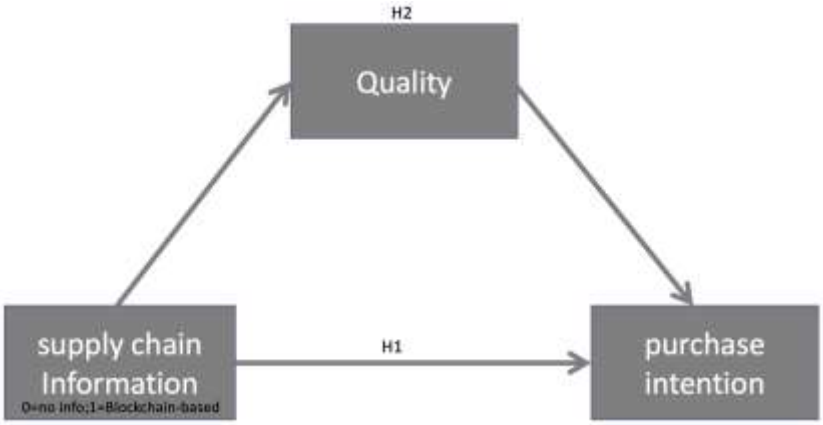

Figure. 1 Theoretical framework summarizing H1 and H2

4. Research design

We designed a randomized controlled experiment to test the conceptual model presented in Figure 1 empirically. Because randomized trials enable researchers to more successfully establish causal linkages, we purposefully opted for an experimental strategy rather than a quasi-experimental or correlational design (Pashley et al., 2020). Through random assignment, we ensured that participants in the treatment and control groups were statistically equivalent at baseline, both in observed and unobserved characteristics.

This experiment aimed to achieve two objectives. First, we examined whether displaying blockchain-based traceability information on a product page directly increased consumers' purchase intentions (H1). Second, we explored whether perceived product quality played a mediating role in this relationship (H2). We selected Lancôme Toner—a premium international skincare product—given its popularity in China and the prevalence of counterfeit concerns. This real-world context provided an ideal setting for investigating how traceability cues influence consumer behaviour.

Figure 2. Interface design comparison between the experimental group (with clickable blockchain-based supply chain traceability) and the control group (with standard non-clickable product information)

4.1 Methodology Overview

We used a one-factor between-subjects experimental design to evaluate our hypothesis. We used traceability information as an independent variable and randomly assigned participants to one of two conditions. In the control group, participants saw a

product page with no traceability cues. In the experimental group, users saw the identical product page but with a blockchain-based traceability link.

We selected *Lancôme Toner*, a premium international skincare product, as the experimental stimulus. This product is widely available on CBEC platforms in China. It is frequently subject to counterfeiting, which makes it highly relevant for studying consumer responses to traceability signals. We designed the product pages to simulate the layout of major CBEC platforms such as Tmall Global and JD Worldwide. In the experimental condition, we embedded a clickable link titled "Blockchain Traceability" into the product page. When clicked, the link displayed detailed information about the manufacturer, distributor, and retailer, mimicking the transparency typically provided by blockchain technology.

We conducted our entire experiment online, targeting Chinese consumers with prior experience in cross-border online shopping. We recruited participants via Credamo , a professional online data collection platform. To ensure data quality, we included only those respondents with a credibility score of 80 or higher and an acceptance rate of at least 70%.

We initially collected 254 responses. After excluding participants without CBEC experience or those who failed attention checks, we retained 219 valid samples for analysis. The final sample consisted of 61.6% female and 38.4% male participants. Most respondents (51.6%) were aged 21–30, followed by 36.6% aged 31–40. In terms of education, 79% held a bachelor's degree, 10.5% a master's degree, 7.8% a junior college diploma, and 1.4% held either a doctoral degree or a high school diploma.Table 2 summarises the demographic characteristics of the final sample, including gender distribution, age range, and education level.

Table 2: Demographic Description for Participants

Construct	**Features**	**Amount**	**Percentage**
Gender	Men	84	38.4%
	Women	135	61.6%
Age	Under the age of 20	8	3.7%
	21-30 years old	113	51.6%
	31-40 years old	78	35.6%
	41-50 years old	13	5.9%
	Above of age of 51	7	3.2%
Degree of education	High School	3	1.4%
	Associate Degree	17	7.8%
	Bachelor's Degree	173	79%
	Master's Degree	23	10.5%
	PhD	3	1.4%

4.2 Measures

We measured two core constructs in this study: perceived product quality and purchase intention. To assess these constructs, we adapted established scales from Dodds, Monroe, and Grewal (1991) to fit the context of cross-border cosmetics consumption.

We reworded all items to ensure contextual relevance and clarity for participants evaluating imported cosmetic products on CBEC platforms. Participants rated their responses using a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree). The complete list of items appears in the Appendix.

We evaluated the reliability and validity of the two scales. The Cronbach's alpha values were 0.888 for purchase intention and 0.882 for perceived product quality, both exceeding the 0.80 threshold, indicating strong internal consistency.

We also assessed sampling adequacy for factor analysis. The Kaiser-Meyer-Olkin (KMO) values were 0.746 for purchase intention and 0.830 for product quality, confirming the suitability of the data for factor analysis.

The factor loading analysis showed that all items loaded strongly onto their respective constructs. For purchase intention, factor loadings ranged from 0.902 to 0.920. For perceived product quality, factor loadings ranged from 0.787 to 0.901. These results indicate good convergent validity, demonstrating that each item effectively represents its underlying latent construct.Table 3 presents the specific measurement items used in the study, along with their original sources and contextual adaptations for the CBEC cosmetics setting.

Table 3 Measurement Items, Sources, and Psychometric Properties

Variable Name	Item	Item source	Cronbach's Alpha	Factor Loadings	KMO
Purchase Intention	P1.I will purchase cosmetics and personal care products on this CEBC.	(Dodds et al., 1991)	0.888	0.902	0.746

	P2.I am positive about purchasing cosmetics and personal care products on this CEBC			0.901	
	P3.I will recommend other people to purchase cosmetics and personal care products on this CEBC			0.92	
Quality	Q1. I believe this cosmetic product is reliable..	(Dodds et al., 1991)	0.882	0.901	0.83
	Q2. This cosmetic product appears to be of high quality.			0.787	
	Q3. This cosmetic product seems to have long-lasting effects.			0.884	
	Q4. This cosmetic product seems safe and dependable to use.			0.874	

4.3 Assessing common method bias

To reduce the risk of standard method bias (CMB)—which may occur when all constructs are measured using the same response format, potentially inflating covariances and inducing systematic response patterns—we implemented both procedural and statistical remedies, following the guidelines proposed by Podsakoff et al. (2003) and Tehseen et al. (2017).

We conducted a pretest to identify and revise any ambiguous items that could lead to biased responses. Additionally, we ensured the anonymity of participants and randomised the order of items to minimise social desirability and priming effects.

To statistically assess the presence of CMB, we applied Harman's single-factor test. We treated perceived product quality and purchase intention as separate constructs, following the approach of Afthanorhan et al. (2021). First, we estimated a single-factor model by assigning all measurement items to a single latent factor. Then, we constructed a two-factor model by assigning the three purchase intention items to the purchase intention construct and the three product quality items to the perceived product quality construct.

As shown in Table 4, the single-factor model exhibited poor fit (χ^2 = 1164.347, df = 21, RMSEA = 0.13, CFI = 0.955, NNFI = 0.932, SRMR = 0.033), whereas the two-factor model demonstrated a significantly better fit (χ^2 = 38.890, df = 13, RMSEA = 0.095, CFI = 0.977, NNFI = 0.963, SRMR = 0.024). A chi-square difference test confirmed the superiority of the two-factor model over the single-factor model ($\Delta\chi^2$ = 1125.457, Δdf = 8, $p < .01$).

These results suggest that common method bias does not pose a serious threat to the validity of our findings.

- Table 4 Model Fit Indices for Harman's Single-Factor and Two-Factor Tests

Model	χ^2 (df)	$\Delta\chi^2$ (df)	RMSEA	SRMR	NNFI	CFI	Model Fit
Single-Factor Model	1164.347(df=21)	-	0.13	0.033	0.932	0.955	Poor Fit
Two-Factor Model	38.890(df=13)	$\Delta\chi^2$ = 1125.457(df=8), p < .01	0.095	0.024	0.963	0.977	Good Fit

4.4 Analysis and results

We conducted a series of analyses to test our hypotheses regarding the effects of blockchain-enabled traceability information on consumer perceptions and behaviours..

4.4.1 Perceived Blockchain Usage (Chi-Square Test)

We first applied a Pearson Chi-square test to assess whether the inclusion of product chain information significantly influenced participants' perceptions of blockchain technology usage on CBEC platforms. The analysis revealed a significant association between exposure to traceability information and the perception of blockchain usage, $\chi^2(1) = 65.654$, $p < .01$. Participants in the

experimental group were more likely to identify the use of blockchain technology, indicating that traceability information serves as an effective signal of technological adoption in the CBEC context.

Table 5 Pearson Chi-Square Results on Perceived Blockchain Usage

	Value	Df	Sig.
Person Chi-square	65.654 a	1	<0.01
N of Valid Cases	219		

4.4.2 Group Differences in Purchase Intention (ANOVA and Descriptive Statistics)

We next examined whether blockchain-based product chain information affected consumers' purchase intentions. The results showed that the experimental group—exposed to traceability information—reported significantly higher purchase intentions than the control group. The experimental group had a mean purchase intention of 5.63 (SD = 0.77), while the control group had a mean of 4.72 (SD = 1.38). A one-way ANOVA confirmed that this difference was statistically significant (p < .001), supporting Hypothesis 1.

Table 6 Group Statistics for Differences in Purchase Intention

	Group	N	Mean	Std. Deviation	Sig.
Purchase Intention	0	109	4.7217	1.37924	<.001
	1	110	5.6333	0.77282	

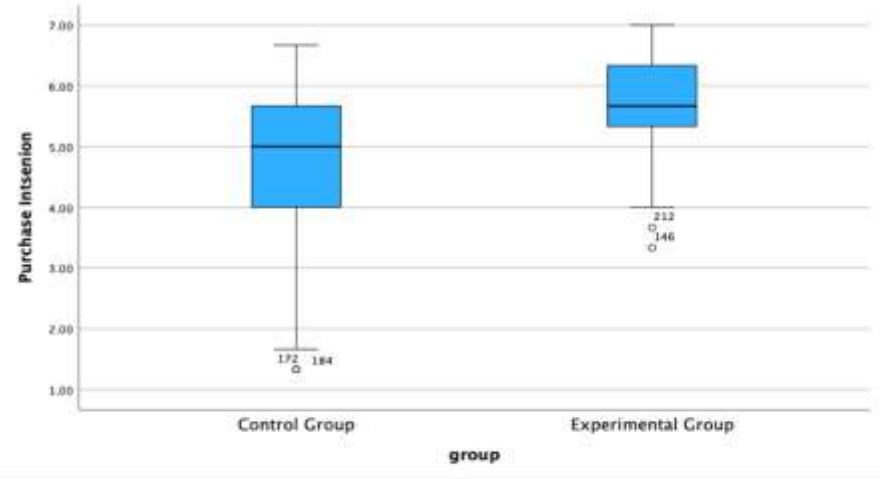

Figure 3. Boxplot of Purchase Intention Across Experimental and Control Groups

Figure 3 displays the distribution of purchase intention scores between the two groups. Group 1 (experimental) had a significantly higher median and more concentrated responses, whereas Group 0 (control) showed a broader range with several low outliers. This suggests that exposure to traceability information not only boosts average purchase intention but also reduces hesitation and variability in consumer responses.

4.4.3 Mediation Analysis (PROCESS Model 4)

We tested Hypothesis 2 using PROCESS Model 4 (Hayes, 2018) with 5,000 bootstrap resamples. In this model, supply chain information (X: 0 = no traceability, 1 = blockchain-based traceability) was modeled as the independent variable, perceived product quality (M: average of Q1–Q4) as the mediator, and purchase intention (Y: average of P1–P3) as the dependent variable. The analysis aimed to examine whether the effect of traceability information on consumer purchase intention was mediated by perceived product quality.

The results indicated that supply chain information significantly increased perceived product quality (a = 0.8109, p < .001), supporting H2. In turn, perceived product quality significantly predicted purchase intention (b = 0.9777, p < .001). However, the direct effect of supply chain information on purchase intention became statistically non-significant when controlling for perceived quality (c′ = 0.1188, p = .258), suggesting a full mediation effect.

Bootstrapping results further confirmed the significance of the indirect effect through perceived product quality, with an effect size of 0.7928 (BootSE = 0.1205, 95% CI [0.5661, 1.039]), as the confidence interval excluded zero. These findings suggest that

the influence of blockchain-based traceability on purchase decisions is primarily channeled through enhanced perceptions of product quality rather than a direct effect.

As shown in Table 7 and Figure 4, the total effect of traceability on purchase intention was 0.9116. After including perceived quality as a mediator, the direct effect dropped to 0.1188 and lost statistical significance, while the indirect effect (0.7928) accounted for the majority of the total effect. This pattern is consistent with a complete mediation model, in line with signaling theory, which posits that traceability mechanisms act as quality signals that influence consumer behavior through perceptual pathways.

Table 7 Mediation Analysis Results

	Effect Value	SE	LLC1	ULC1	Effect Size
Total Effect	0.9116	0.1509	0.6142	1.209	
Direct Effect	0.1188	0.1047	-0.0876	0.3253	86%
Mediated Effect	0.7928	0.1195	0.5661	1.039	13%

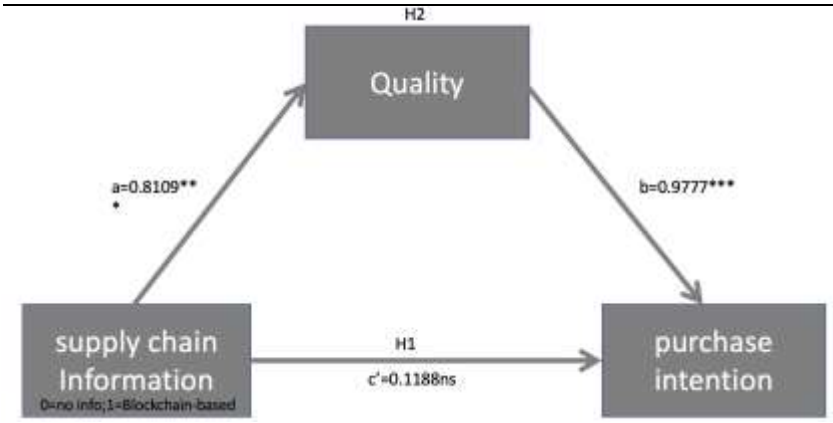

Figure 4 Mediation Model of the Effect of Traceability Information on Purchase Intention

5 Discussion

In recent years, blockchain technology has attracted increasing scholarly attention for its role in improving transparency and traceability in consumer-facing supply chains. Referring to extant literature suggesting that traceability information can reduce information asymmetry and enhance consumer trust, we investigate whether blockchain-based traceable supply chain information influences consumers' perceived product quality and, in turn, their purchase intentions. Our research was guided by two questions, respectively investigating: (1) whether traceable supply chain information enhances consumers' perception of product quality, and (2) whether this information indirectly shapes purchase intention via perceived product quality.

The online experiments tested these hypotheses by assigning participants to either a control group (no traceability information) or a treatment group (with blockchain-based supply chain information), simulating a realistic shopping experience on CBEC platforms. This experimental approach reflects growing recognition of online experiments in consumer behaviour research, offering both internal validity and ecological relevance (Duong et al., 2024). The focal product—Lancôme toner—was selected due to its popularity in China and its association with counterfeit risks, which makes it a suitable case for studying authenticity concerns and signal processing in high-involvement categories.

The results of the study confirmed that consumers in the experimental group exhibited significantly higher purchase intentions than those in the control group. We theorized that this result can be explained by a ceiling effect: when credible product-chain information is presented, it substantially reduces consumer concerns regarding product authenticity and quality, leading to elevated behavioral intentions. Based on this result, a mediation analysis further revealed that perceived product quality fully mediated the relationship between traceable information and purchase intention, suggesting that cognitive appraisal serves as a key psychological link between technological signals and consumer action .

The findings of our study extend previous research by integrating blockchain technology into the framework of signaling theory. This research stream was established on a theoretical level by Connelly et al. (2011), who proposed that information asymmetry can be mitigated through credible signals. While past studies have examined brand, price, or warranty as signals (Erdem, 1998) our study contributes by demonstrating that blockchain-enabled supply chain transparency—anchored in tamper-proof and verifiable data—acts as a technology-driven signal that is processed cognitively by consumers, especially in the context of imported cosmetics.

Furthermore, on a global scale, major CBEC platforms have begun adopting blockchain to address authenticity concerns. For example, Tmall Global launched a traceability system enabling customers to scan QR codes and access information on product origin, customs clearance, and inspection records (Cointelegraph, 2020). Similarly, JD Worldwide introduced "JD Smart Check" in

2023, which integrates blockchain and serialization technologies to combat counterfeiting and boost consumer confidence (Yang, V., 2023). These real-world applications reinforce our empirical findings and emphasize the importance of transparency technologies in strengthening trust and security in cross-border online transactions.

5.1 Theoretical Contributions and Implications

This study offers several theoretical contributions to the literature on blockchain technology, consumer behaviour, and CBEC.

First, this research extends signaling theory into a novel technological context by demonstrating how blockchain-enabled traceability functions as an intentional and credible signal in digital marketplaces. Prior applications of signaling theory have focused primarily on traditional cues such as warranties, brand reputation, or price (Boulding & Kirmani, 1993; Erdem, 1998). By contrast, this study empirically verifies that blockchain-based supply chain information serves as a technology-driven signal that reduces information asymmetry and enhances perceived product quality in the context of CBEC cosmetics. In doing so, it advances the theoretical boundary of signaling theory by integrating it with emerging technologies.

Second, the study highlights perceived product quality as a key psychological mechanism that mediates the effect of blockchain-based signals on consumer behaviour. While previous literature has acknowledged the role of trust and risk perception (Duong et al., 2024; Li, 2022), relatively few studies have isolated perceived quality as a full mediator. Our findings reinforce the importance of cognitive evaluations in digital purchase environments and provide empirical support for a sequential process: traceability → perceived quality → purchase intention.

Third, this study contributes to the consumer behaviour literature in CBEC settings, a context that has received limited attention in blockchain research. Existing blockchain studies have primarily focused on food or agricultural products (Bosona & Gebresenbet, 2023; Ying et al., 2023), whereas this research explores the cosmetics sector—a domain where product safety, authenticity, and consumer trust are paramount. By demonstrating that blockchain traceability enhances perceived product quality and purchase intentions even in experience-based, appearance-sensitive categories, the study enriches our understanding of consumer decision-making in high-involvement product scenarios.

Finally, this study provides a mechanism-oriented view of how consumers process technological information. Rather than assuming that blockchain labels automatically trigger favourable responses, the results show that consumer cognition—specifically perceived product quality—is an essential link in the decision process. This finding offers a more nuanced and theory-driven explanation of how blockchain applications influence market outcomes.

5.2 Practical Implications

The findings of this study offer important practical implications for CBEC platforms, brand managers, and policymakers aiming to enhance consumer trust and encourage purchasing behaviour through technological transparency.

First, the results demonstrate that blockchain-based supply chain traceability information, when clearly presented, significantly enhances consumers' perceived product quality, which in turn increases purchase intention. This underscores the strategic value of traceability information as a consumer-facing asset, not just a backend logistics tool. In CBEC contexts—where information asymmetry is prevalent and physical inspection is impossible—making traceability information accessible and credible is essential to strengthening consumer trust.

Second, the mediating role of perceived product quality suggests that CBEC platforms and brands should focus not only on adopting blockchain for operational traceability but also on communicating quality-relevant supply chain data to consumers. This includes clearly presenting information such as product origin, customs clearance, transportation milestones, and inspection records in ways that are intuitive and trustworthy. The effectiveness of blockchain in influencing consumer behaviour depends on how well these signals are understood and interpreted as indicators of product reliability and authenticity.

Third, the study's findings are consistent with industry practice. For instance, Alibaba's Tmall Global has implemented a blockchain-based traceability system that enables consumers to scan QR codes and view detailed supply chain information, including the origin, customs declarations, and quality inspection records of imported products (Cointelegraph, 2020). Similarly, JD Worldwide introduced the "JD Smart Check" program in 2023, which integrates blockchain technology with serialisation and anti-counterfeiting codes to provide transparent, tamper-proof supply chain records (Yang, V., 2023). These initiatives reflect the growing emphasis on transparency and traceability as a means of enhancing platform security and building consumer confidence in cross-border transactions.

Finally, from a policy perspective, the results suggest that regulatory bodies could support the broader adoption of blockchain traceability by encouraging standards for data interoperability and promoting the disclosure of verifiable product chain information. Especially in high-risk product categories such as cosmetics, providing blockchain-backed supply chain transparency may serve as an effective mechanism to combat counterfeiting, improve public safety, and foster sustainable cross-border trade.

5.3 Limitations and Future Research

Although this study provides meaningful insights into the impact of blockchain-based supply chain information on consumer behaviour in CBEC, several limitations should be acknowledged. First, the experimental design employed a fictional product

presentation using a single brand and product (Lancôme toner), which may limit the generalizability of the findings to other product types or brands. Second, the study focused exclusively on Chinese consumers with CBEC shopping experience, potentially limiting cross-cultural applicability. Third, while perceived product quality was examined as the sole mediator, other psychological constructs—such as perceived risk, trust, or perceived value—may also play important roles in shaping purchase intentions but were not considered. Finally, the experimental manipulation relied on a binary treatment (presence or absence of blockchain-based information), which may oversimplify how real-world traceability systems are implemented or perceived in diverse online environments.

Future studies should explore a broader range of product types and brands to improve generalizability. For instance, categories such as food, pharmaceuticals, or luxury fashion—which also involve high consumer sensitivity to authenticity and safety—could offer valuable comparative insights. Additionally, researchers could collaborate with actual CBEC platforms or brands to test real-time traceability systems in a live shopping environment, thereby enhancing ecological validity.

To deepen the understanding of how consumers process traceability signals, future research may incorporate additional psychological variables such as trust, perceived value, or blockchain familiarity. These variables may function as parallel mediators or as moderators that shape the strength of the quality-perception pathway. For example, it would be insightful to test whether the mediating effect of perceived product quality is stronger for consumers with higher technological awareness.

As CBEC continues to expand globally, future research should investigate whether the effects of blockchain-based supply chain information differ across cultural or national contexts. Cultural dimensions such as uncertainty avoidance, power distance, or familiarity with digital technologies may influence how consumers interpret supply chain transparency. A cross-cultural comparative design could help uncover nuanced differences in consumer cognition and behaviour.

Finally, further studies could examine how the format, design, and interactivity of blockchain-based traceability information influence consumer perception. Whether traceability data is presented through interactive timelines, certification icons, QR-code scans, or embedded smart contracts may result in varying levels of perceived credibility and engagement. Understanding how interface design enhances the signaling effect of traceability data would offer practical guidance for e-commerce platforms and UX designers.

6 Conclusion

This study presents several important takeaways. First, it confirms that blockchain-based supply chain information significantly enhances consumers' perceived product quality in the context of CBEC. Then, it demonstrates that perceived product quality serves as a full mediator between supply chain transparency and purchase intention. Therefore, rather than functioning merely as a technological innovation, blockchain-enabled traceability operates as a psychological signal that shapes consumers' cognitive evaluations and behavioral outcomes.

Secondly, our research provides empirical evidence that enriches prior theoretical models. Earlier studies have suggested that blockchain technology may build trust and improve transparency in sectors such as food and agriculture (Bosona & Gebresenbet, 2023; Duong et al., 2024). However, by comparing a cosmetics product with and without traceability features, this study reveals that even in appearance-sensitive, non-edible categories, blockchain information significantly influences purchase intention, primarily through perceived product quality. This extends the boundary of prior findings and suggests that blockchain can effectively address product credibility concerns across diverse industries.

The results of this research contribute to a more nuanced understanding of how technological signals function in consumer decision-making. This leads to a broader implication: transparency mechanisms such as blockchain not only improve operational logistics but also serve as strategic tools for shaping consumer perceptions. Existing research has long viewed blockchain as a backend supply chain tool; however, this study affirms its role in the consumer interface by demonstrating its influence on perceived quality and purchase motivation. As CBEC platforms continue to evolve, the ability to communicate supply chain authenticity through blockchain may become an essential differentiator in global online retail.

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