



Research article

Evaluating the impact of blockchain adoption on equilibrium pricing in agri-product supply chain with heterogeneous power structures

Yueyang Gan¹, Xianrong Hu¹, Tonghua Yang², Fangbing Liu¹, Junke Qiu¹ and Xiaoqing Huang^{1,*}

¹ School of Business, Jiangxi University of Science and Technology, Nanchang 330038, China

² Vocational Normal College, Jiangxi Agricultural University, Nanchang 330045, China

* **Correspondence:** Email: huangxiaoqing@jxust.edu.cn; Tel: +86-15070094301.

Abstract: In the context of the increasingly prominent trust crisis in the agricultural product supply chain, this paper constructs a two-level supply chain system consisting of agricultural cooperatives and live-streaming e-commerce platforms. By considering two scenarios of including or not including blockchain technology and combining three power structures of manufacturer-led, retailer-led, and centralized decision-making, this paper establishes six game models to systematically examine the equilibrium characteristics of traceability level, blockchain investment level, retail price, and the profits of supply chain members. The research results show that the degree of consumers' distrust will significantly weaken the overall profitability of the supply chain; the introduction of blockchain technology can not only effectively avoid trust losses but also serve as a strategic incentive measure to encourage supply chain members to jointly improve the product traceability level; the trust gain coefficient has a positive marginal promoting effect on all decision variables; and regardless of whether blockchain is introduced or not, the centralized decision-making model always performs better than the decentralized decision-making model in terms of performance. The findings provide theoretical support for digital supply chain management and contribute to the understanding of how blockchain-enabled traceability promotes information transparency, consumer trust, and long-term supply chain development.

Keywords: agricultural product (agri-product); traceability level; supply chain (SC); blockchain; stackelberg game; heterogeneous power structures

Mathematics Subject Classification: 91A10, 90B50, 90C90

1. Introduction

In recent years, quality safety incidents, label discrepancies, origin fraud, and food fraud in the agricultural product (agri-product) supply chain (SC) have continued to surface, undermining the overall trust that consumers have in the agri-product market, business entities, and regulatory systems. Compared to general industrial products, agri-products have stronger attributes of experience goods and credit goods. Consumers often find it difficult to accurately identify their true quality, safety level, production methods, and circulation conditions before purchase and also have difficulty fully verifying their intrinsic properties after purchase. Therefore, the agri-product SC inherently has a strong information asymmetry [1,2]. Current research indicates that in the current market environment, consumers are highly sensitive to food safety and verifiable information [3]. The level of trust significantly influences their willingness to pay for and make purchasing decisions regarding traceable food. Once consumers are unable to obtain verifiable product information, they are more likely to have a sense of risk and lower their confidence in making a purchase. Meanwhile, further research on traceable food has revealed that food safety incidents will continue to erode consumers' trust in the SC [4,5], while the authenticity, completeness, and availability of traceability information will significantly influence consumers' willingness to purchase related products [6]. When consumers encounter green agri-products, due to the lack of transparent understanding of production techniques and input materials, the "lemon effect" further exacerbates the uncertainty of their purchasing decisions. If there is a significant information asymmetry between buyers and sellers, high-quality products cannot obtain a quality premium in the absence of credible signals [7]. To address the issue of information asymmetry, product traceability has been widely introduced into the agricultural SC, aiming to rebuild consumer trust through information dissemination.

The traditional traceability approach has several drawbacks, such as fragmented information and lagging updates, making it difficult to convey key information, such as product origin and quality, to consumers in a complete and verifiable manner. Kafeza et al. [8] pointed out in their literature review that traditional SC information systems have difficulties in ensuring transparency and traceability, which has exacerbated food safety risks and consumer trust crises. This technical-level trust gap makes it difficult for consumers to effectively reduce their distrust of the quality of products in the SC through existing mechanisms. When the traceability information consumers obtain fails to meet their expectations, their traceability expectations are violated [9]. When consumers have a clear demand for traceability but cannot obtain sufficient, genuine, clear, and useful information, or when the traceability information they actually receive does not match their expectations, significant expectation differences will arise. These differences will reduce consumers' perception of food quality and further inhibit their purchase intentions. When consumers learn that their positive expectations may not be fulfilled, their trust in the brand and attitude towards the product both decline, thereby reducing their purchase intentions. In the digital environment, this dissatisfaction is also prone to being externalized as negative comments and spread [10]. Therefore, if traditional traceability mechanisms fail to effectively align with consumers' information needs and security expectations, they may instead cause damage to a company's profits due to the spread of negative evaluations.

In the face of the trust dilemma and negative evaluation risk associated with traditional traceability, the introduction of blockchain technology provides a solution for information governance in the agri-product SC. Leveraging its core features, such as decentralized ledgers, immutable data on the chain, and automatic execution of smart contracts, blockchain enables consumers to obtain truly trustworthy

data covering the entire product lifecycle [11]. The direct effect of blockchain lies in significantly reducing consumers' perceived uncertainty. Research shows that the depth of information conveyed by blockchain traceability labels can effectively dispel consumers' doubts about product quality, thereby enhancing their purchase intention and brand trust [12]. More importantly, the immutability of blockchain can simultaneously restore consumers' dual trust in retailers and producers [13]. This means that consumers' distrust will be eliminated with the introduction of blockchain, fundamentally preventing negative evaluation losses caused by the gap in expectations. At the same time, the introduction of blockchain is not a technological addition; its operation requires a certain investment. The level of blockchain investment not only affects the transparency of traceability information but also indirectly affects the pricing strategy and profit distribution of the SC by changing the game pattern of SC members [14]. However, the investment in blockchain is constrained by multiple factors, such as technical complexity and cost uncertainty [15], and its effectiveness depends on the intensity of blockchain investment and the collaborative participation of each node in the SC [16].

It is worth noting that the introduction and operation of blockchain technology do not occur in a vacuum within the system, but are deeply integrated into the specific power structure of the SC. In the actual agri-product circulation system, there are different power allocation models [17]. Under heterogeneous power structures, the members of the SC exhibit significant differences in terms of the attribution of pricing rights, the proportion of cost sharing, and the incentives for technological investment [18]. Specifically, in a structure where manufacturers are the leaders of the game, manufacturers have priority in setting prices, while retailers are in a follower position. In a structure where retailers are the leaders, retailers with channel advantages hold the dominant position in setting prices, and the profit margins of manufacturers may be compressed. This difference in leadership rights not only affects the traditional pricing and profit distribution patterns but also influences the investment decisions of blockchain [19,20]. At the same time, the power structure has a significant impact on the willingness of SC members to invest in traceability. The equilibrium levels of traceability under the manufacturer-led and retailer-led models may differ significantly [21]. When blockchain is introduced as a governance tool that requires continuous cost investment, different power configurations will result in completely different game equilibria [22]. If only the blockchain investment and pricing strategies under a single power structure are examined, it is equivalent to assuming that all agri-product SCs have a homogeneous bargaining power structure. This is obviously inconsistent with the actual coexistence of diverse channel power ecosystems. Therefore, it is necessary to construct three game models: manufacturer-led, retailer-led, and centralized decision-making. Systematically compare the differences in the optimal investment level of blockchain and the pricing strategies under heterogeneous power structures [23]. Through this multi-model comparative analysis, this paper aims to answer a problem with both theoretical and practical value: Which power structure is more conducive to stimulating high-level blockchain investment, more effectively restoring consumer trust, and improving the overall performance of the SC?

2. Literature review

2.1. Research on traceability level

As a key variable in the SC of agri-products, the traceability level has attracted the wide attention of the academic community because of its impact on consumer behavior and SC performance.

Regarding the decisions and effects related to the traceability level, scholars have conducted in-depth research from various perspectives. Zhang [24] constructed an analysis framework for the agri-product SC traceability system based on the Internet of Things and blockchain. The study found that the breadth of traceability information collection and the real-time nature of data transmission could significantly enhance the information transparency and operational efficiency of the SC. Lv et al. [25] and others' review of literature related to agri-product traceability further pointed out that the completeness, accuracy, and real-time nature of traceability information are the key dimensions determining the traceability level. At the consumer behavior response level of traceability, Lin [26] found that consumers have a significant preference for verifiable traceability information, and the intensity of this preference is positively correlated with consumers' risk perception of food safety. Zhou [27] also emphasized that the improvement of the traceability level can enhance consumers' confidence in product quality. Some scholars further explored the impact of traceability level on the overall performance of the SC. Li et al. [28] constructed a comprehensive model for the green traceability level of agri-product SCs and found that the improvement of the traceability level not only helps to ensure product quality and safety, but also can indirectly enhance the efficiency of the SC by reducing the efficiency loss caused by information asymmetry. Tan et al. [29] demonstrated that enhancing the traceability level can curb information fraud by increasing information transparency, thereby improving the overall performance of the SC. In terms of the correlation between consumer trust and traceability level, Yao and Zhang [30] indicated that improving the traceability of agri-products can effectively reduce consumers' uncertainty regarding product quality and safety by enhancing the transparency and credibility of information. Prashar et al. [31] also found in their analysis of the agri-product market that traceability has significant advantages in enhancing consumer trust and ensuring food safety. In summary, the existing literature has confirmed the significant impact of traceability levels on SCs from multiple dimensions. However, it mostly treats them as exogenous parameters or focuses only on the unilateral response of consumers. It rarely internalizes them and incorporates them into the analysis of multi-power structure games. At the same time, the negative evaluation losses caused by the expectation gap of traceability have not been fully addressed, which provides theoretical expansion space for this paper to introduce the mechanism of consumer distrust and negative evaluations.

2.2. Consumer distrust and negative reviews

In the context of information asymmetry in the agri-product SC, consumers' lack of trust and negative online reviews have become key factors affecting the sustainable development of the SC. Ta and Duong [32] found that trust has a constraining effect on consumption decisions. Modica et al. [33] further confirmed that there is a significant positive correlation between consumers' trust in products and their willingness to pay a premium. The higher the level of trust, the stronger the willingness of consumers to pay a premium to verify the food. Gao [34] pointed out that the higher the degree of trust consumers have in the source of traceability information release, the stronger their willingness to refer to traceability information to diagnose product quality. Wang et al. [35] found that online word-of-mouth has a significant impact on consumers' perceived value. When consumers' distrust accumulates to a certain extent, negative evaluations become the main form of their emotional expression and behavioral response. Du et al. [36] investigated that both the proportion of negative online comments and the severity of mistakes have a significant negative impact on the purchase intention of potential customers. Halim et al. [37] also conducted a study, which indicated that intense negative electronic

word-of-mouth significantly reduced consumers' purchase intentions to a greater extent than low-intensity negative word-of-mouth. At the level where negative evaluations are transmitted to the enterprise's profits, Ni et al. [38] examined the impact of negative corporate reputation on financing scale from the perspective of the life cycle theory. Hu et al. [39] confirmed that the number of negative reviews would significantly reduce the sales volume of fresh agri-products in e-commerce. Qing et al. [40] used agri-products as the empirical object and found that negative comments related to the product could reduce consumers' purchase intentions. Yao and Feng [41] also conducted research on fresh aquatic products and demonstrated that consumers' perceived risks when reading negative online comments about product attributes were significantly higher than those of service-related negative comments, and their purchase intentions were also lower. In summary, most existing literature regards consumers' distrust and negative evaluations as exogenous factors. Few studies internalize them into traceability and blockchain or incorporate them into the game analysis under heterogeneous power structures, thus providing an entry point for this research.

2.3. The impact of blockchain on SC

In the SC, the introduction of blockchain not only changes the way information is transmitted but also profoundly influences the pricing decisions, coordination efficiency, and overall performance of the SC. Vu et al. [42] pointed out, based on research in the food industry, that the adoption of blockchain can significantly enhance SC performance. Feng et al. [43] showed that the investment level of blockchain directly affects the optimal pricing and quality decisions. When the investment cost of blockchain is in a reasonable range, the SC members can achieve Pareto improvement of profits. Ma et al. [44] further incorporated consumer trust into the analytical framework and found that the adoption of blockchain technology can enhance the overall efficiency of e-commerce SCs through the trust restoration mechanism. Yang and Yu [45] demonstrated from the perspective of operational performance that blockchain has a significant positive effect on the operational performance of the SC. Sola et al. [46] revealed the dual mediating role of SC transparency and supplier trust between the adoption of blockchain technology and new product development, providing a new perspective for understanding the value transmission path of blockchain investment. Cho et al. [47] found that blockchain technology has a significant enabling effect on lean SC management. In terms of the cost threshold and decision boundary for blockchain implementation, Samuel et al. [48] confirmed that blockchain technology has a positive impact on the sustainability of SCs and that there is a marginal diminishing effect between the investment level and performance improvement. Xu et al. [49] research indicated that information sharing of demand forecasting under blockchain technology can significantly enhance SC efficiency. Dong et al. [50] then explored the mechanism of blockchain adoption on the SC system and enterprise performance. Javadi et al. [51] focused on the impact of blockchain technology on SC production strategies, and their research revealed that the level of blockchain investment could significantly improve production planning and inventory management strategies. Duong et al. [52] examined the impact of blockchain-enabled food traceability systems on consumer trust and purchase behavior, demonstrating that blockchain technology can enhance trust through improved information transparency. Zhang et al. [53], in the dual context of fairness concerns and blockchain subsidies, revealed the mechanism of the impact of blockchain investment on the pricing strategy of the agri-product SC. Wang et al. [54] explored the issue of SC financing optimization driven by blockchain and confirmed that blockchain technology can improve the

operational efficiency of the SC. Pang et al. [55] reviewed blockchain-based agricultural traceability systems and highlighted the role of blockchain technology in improving SC transparency and traceability. Niu et al. [56] constructed a pricing and coordination model for agri-product SCs under blockchain empowerment and found that blockchain investment can effectively improve the coordination efficiency of the SC. In summary, the introduction of blockchain technology can significantly enhance the transparency and traceability of the SC, strengthen consumer trust, improve pricing and coordination efficiency, and have a positive driving effect on the overall performance of the SC.

2.4. The impact of heterogeneous power structures on SC

As a key institutional variable that affects the game behavior and decision-making equilibrium of members, the power structure of the SC has a profound impact on pricing strategy, quality input, and technology adoption. Xue et al. [57] explored the equilibrium decisions of food SCs with heterogeneous power structures and found that the power structure could significantly regulate the transmission effects of subsidy policies and consumer preferences. Cao et al. [58] pointed out that the power structure affects the brand strategies of agri-product SCs: when retailers are dominant, they tend to introduce their own brands to enhance their bargaining power; when manufacturers are dominant, they focus on controlling brand premiums and channel pricing power. Gao et al. [59] discovered in the closed-loop SC that the channel power structure influences the selection of recycling models. Wan et al. [60] found in retail SCs that the power structure can significantly change the equilibrium choices of promotional strategies and member profit distribution. Liu et al. [61] focused on the live-streaming e-commerce SC and revealed how the ownership of dominance regulates the interaction between marketing investment and pricing strategies. In terms of power structure and product quality decision-making, Fan et al. [62] found that the power structure influences the decisions of SC members and there are significant differences in the equilibrium strategies under the manufacturer-led and retailer-led models. Ren and Luo [63] examined the joint decision-making and coordination mechanisms of product quality and marketing efforts under heterogeneous power structures, and the research showed that the coordination efficiency of contracts under power symmetry and asymmetry structures has essential differences. Zhang et al. [64] found that the power structure affects quality decisions: when the retailer leads, there is a tendency to lower the quality threshold to expand sales volume, and when the manufacturer leads, more emphasis is placed on brand premium and signal transmission. Liu et al. [65] studied the interaction relationship between channel selection and SC transparency under heterogeneous power structures and found that the allocation of channel power can significantly regulate the marginal contribution of transparency investment to SC performance. Zhao et al. [66] analyzed the impact of heterogeneous power structures in the context of smart agriculture on SC pricing strategies, revealing the dual interaction effect of technological investment and power structure. Xu et al. [67] investigated the enterprise social responsibility decisions and the design of dual collaborative contracts under heterogeneous power structures in the fresh produce SC and found that the change in power structure would alter the coordination efficiency of the contract. The existing literature fully demonstrates the impact of power structure on the SC but few incorporate continuous blockchain investment, consumer distrust, and negative evaluation losses into the framework and systematically compare the equilibrium differences under the three power structures. This provides a clear research space for the construction of the model in this paper.

Table 1. Comparison table of this article with related literature.

References	Traceability level	Consumer distrust and negative review losses	Blockchain	Heterogeneous power structures	Research topic	This article contribution
[24]	√		√		The blockchain-based agricultural product traceability system.	Without considering the differences in power structures, without modeling consumer distrust, this article introduces three comparisons of power structures.
[25]	√		√		Literature review on blockchain traceability.	This review paper, lacking a game theory model, constructs a Stackelberg game and derives the equilibrium solution.
[29]	√		√		Blockchain traceability ensures the authenticity of information.	This paper employs evolutionary game theory, which does not consider power structures; it uses Stackelberg game theory.
[32]			√		The impact of blockchain on organic food consumption.	Empirical research, without a game theory model; this paper models from the perspective of supply chain decision-making.
[40]		√			The impact of negative online reviews on agricultural product sales.	Empirical research was conducted, but no modeling was performed. This paper incorporates the endogenization of negative review losses into the profit function.
[44]	√	√	√		The impact of blockchain on consumer trust in the e-commerce closed-loop SC.	Considering only a single power structure, this paper systematically compares three power structures.
[57]	√			√	The impact of government subsidies and consumer preferences on food SC traceability.	This paper does not consider blockchain; it endogenizes blockchain investment levels and derives the threshold condition for the trust gain coefficient.
[61]		√	√		Decision-making under different power structures in the live-streaming e-commerce SC.	This article does not cover blockchain and traceability; it focuses on blockchain + traceability + power structure.
[66]	√			√	Pricing and coordination of smart agriculture technologies under different power structures.	This article does not utilize blockchain technology; it does not consider consumer distrust; it introduces the concepts of blockchain and negative review losses.
This article	√	√	√	√	Agricultural SC decision-making with different power structures in the context of blockchain.	

As can be seen from Table 1, extensive research has been conducted on key factors, such as the traceability level of the agri-product SC, consumer distrust and negative review losses, the level of blockchain investment, and heterogeneous power structures, achieving rich theoretical results and management inspirations. However, the existing literature still has the following shortcomings: First, most studies focus on the impact of a single factor on the agri-product SC, such as only discussing the traceability level of the product, without systematically analyzing the interaction between the two in the context of introducing blockchain. Secondly, most studies ignore the systematic comparison of equilibrium strategies and performance differences under three typical structures in the blockchain context, namely manufacturer-led, retailer-led, and centralized decision-making. Third, most studies on blockchain adoption in game theory research consider it as a fixed “technology choice (use or not use)”, rarely treating the level of blockchain investment as a continuous decision variable, and failing to deeply explore the impact of consumers’ trust coefficient in blockchain on SC decisions.

In view of this, this paper conducts research on the pricing and coordination issues of the agri-product SC in the context of blockchain empowerment. Based on the consideration of the degree of consumer distrust and the effect of trust enhancement, a game model for the agri-product SC is constructed, which includes the level of traceability and the level of blockchain investment. Considering the different situations before and after the introduction of blockchain, this paper starts from three power structures: manufacturer-led, e-commerce platform-led, and centralized decision-making, and builds six game models. It systematically analyzes the optimal pricing, traceability level, blockchain investment level, and profit distribution mechanism of the SC members under different circumstances. At the same time, this paper further compares the changes in retail prices, traceability decisions, trust gain coefficients, and overall SC performance before and after the introduction of blockchain, revealing the mechanism of blockchain technology in alleviating consumer distrust, improving SC transparency, and improving operational performance. On this basis, this paper uses game theory methods to solve the model equilibrium and, through numerical simulation, examines the differences in SC performance under the interaction of blockchain investment and power structure to provide a theoretical basis and management implications for the application and differentiated decision-making of blockchain technology in agri-product SCs.

The main innovations of this paper are as follows:

(1) This study, from the perspective of heterogeneous power structures, constructs a pricing and investment decision model for agri-product SCs, and compares the optimal strategies under three power configurations (i.e., manufacturer-led, retailer-led, and centralized decision-making). Before the introduction of blockchain technology, incorporating the negative evaluation losses caused by the mismatch between the degree of consumer distrust and their traceability demands and expectations into the profit analysis framework effectively depicted the impact of consumer trust deficiency on demand and profits under the background of information asymmetry, thereby deepening the theoretical understanding of the pricing and operation mechanism of the agri-product SC.

(2) This paper introduces blockchain technology; analyzes its role in improving information transparency, enhancing SC credibility, and alleviating consumer distrust; and explores the influence of consumers' trust coefficient in blockchain on SC decisions. By integrating blockchain input levels, trust gain coefficients, and key variables, the study examines the profitability condition for blockchain adoption and its impact on the pricing and investment strategies of SC participants. It further reveals the differential effects of blockchain technology on SC performance and strategic decisions under heterogeneous power structures.

3. Problem description and model assumptions

3.1. Problem description

This paper considers a two-level agri-product SC consisting of agricultural cooperatives and e-commerce platforms. The SC can operate under either a non-blockchain governance mode or a blockchain governance mode. Under the non-blockchain mode, cooperatives improve product traceability through a conventional traceability system and provide the products to e-commerce platforms, which are responsible for terminal sales. Because source information and quality attributes are not fully verifiable, consumers may distrust the products and negative evaluations may further reduce market demand.

Under the blockchain mode, the cooperative has completed the basic deployment of the blockchain-based traceability system and subsequently determines the level of incremental blockchain investment. The cooperative bears the corresponding fixed deployment cost and variable investment cost. Conditional on the selected governance mode, cooperatives and e-commerce platforms make pricing, traceability-effort, and investment decisions according to the decision sequence specified in each model. The adoption decision is made before these operational decisions.

Accordingly, the paper considers six conditional decision scenarios under three power structures (i.e., cooperative-led, e-commerce-platform-led, and centralized decision-making), with each power structure examined under both the non-blockchain and blockchain governance modes. The corresponding decision sequences are presented in Figure 1.

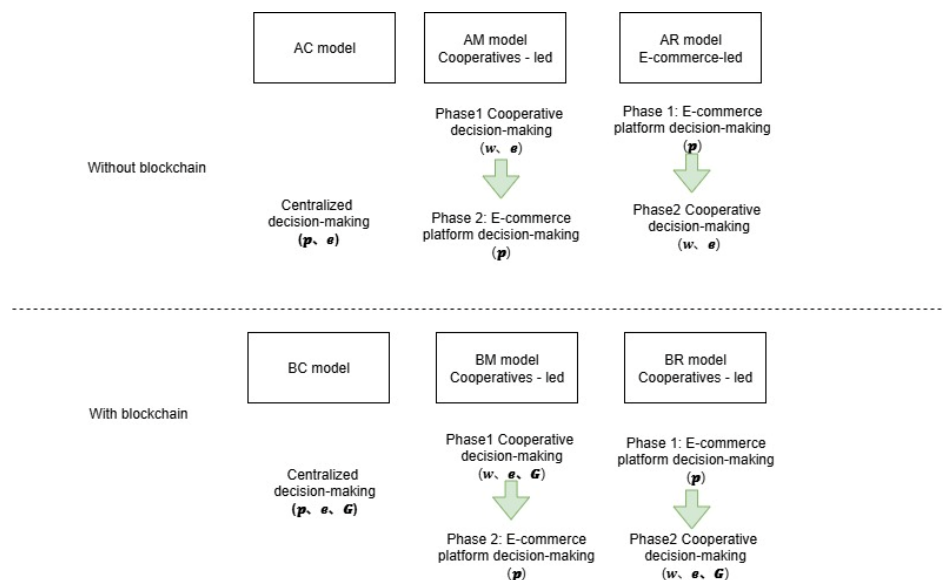


Figure 1. Model decision sequence diagram.

Figure 2 provides a description of the SC relationship. Due to the natural distrust of the source and quality information of agri-products, consumers often have a strong demand for traceability. When the requirement for traceability is not fully met, consumers find it difficult to form a stable quality expectation before purchasing. The opacity of product information will increase the deviation in consumers' judgment of the actual quality, making the actual experience after purchase more likely to differ from the expectation, thereby reducing consumer satisfaction and increasing the possibility of negative evaluations. Therefore, this paper argues that consumer distrust does not directly lead to negative evaluations but rather, by increasing information uncertainty and the risk of expectation deviation, it further affects consumers' evaluation behavior. When such negative evaluations accumulate continuously, it will further weaken the stability of cooperation between cooperatives and e-commerce platforms and have a negative impact on the long-term sustainable operation of the agricultural product SC. The introduction of blockchain technology can improve the information trust mechanism in the SC. By providing immutable, traceable data, it enhances consumers' ability to verify product quality and source information, reduces consumers' distrust, and thereby reduces the loss of negative evaluations caused by information opacity and expectation deviation. In this case, the trust,

friction, and reputation risks faced by supply chain members will be significantly reduced; the market circulation efficiency of agricultural products and the overall sustainability of the SC will be improved; and thus promote the sustainable development of the SC.

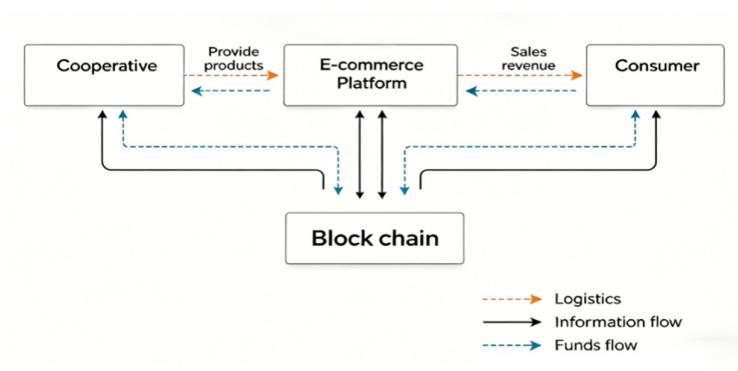


Figure 2. Description of SC relationship.

The relevant parameters and their meaning in this article are shown in Table 2.

Table 2. Parameter meaning table.

Parameter	Meaning
a	Potential market demand
b	Price elasticity coefficient
c	Agricultural production costs
r	The utility of the traceability effort
$g(g_0)$	Bad rating rate (initial bad rating rate)
x	Consumer distrust level
l	Consumers' perception of the degree of distrust
d	Marginal effectiveness of the traceability effort
w	Agri-product wholesale prices
e	Traceability level
p	The market price
G	Blockchain investment level
k	Traceability level cost coefficient
k_g	Blockchain input level cost coefficient
h	Blockchain trust gain coefficient
C_b	The fixed cost of blockchain investment
D	Market demand
p	Agricultural cooperative profit
π^r	Live electric business platform profit
π^c	SC comprehensive profit

3.2. Basic assumptions

Assumption 1. Without loss of generality, according to reference [68], the relationship between traceability level and traceability cost can be assumed as: $C_{(e)} = ke^2/2$, e represents the traceability level. k represents the traceability level cost coefficient, and $k > 0$. It reflects that an improvement in the level of traceability will lead to an increase in traceability costs. This article considers the situation where the traceability costs are borne by the manufacturer.

Assumption 2. Traceability enhances consumer trust by providing transparent information, thereby reducing the negative evaluation rate caused by information asymmetry. Considering the background of this study, based on the previous work [69], under the non-blockchain mode, g_0 denotes the proportion of transactions that generate negative reviews associated with unverifiable product-origin or quality information. It is given by $g = g_0 - de$, where g_0 is the baseline negative-review rate, $d > 0$ measures the effectiveness of traceability effort in reducing such reviews, and e is the traceability effort level. The condition $0 \leq g \leq 1$ is imposed. Let l denote the monetary loss borne by the live electric business platform per unit of negatively reviewed transactions. Therefore, glD represents the platform's expected monetary loss caused by negative reviews.

Assumption 3. Following [70], the variable cost of blockchain investment is assumed to be a quadratic function of the investment level: $C_{(G)} = k_g G^2/2$, where $k_g > 0$ is the variable-cost coefficient. The cooperative is assumed to be the blockchain adopter and bears the fixed deployment cost C_b and the variable investment cost $C_{(G)}$. The quadratic blockchain investment cost is adopted to represent the increasing marginal cost of blockchain implementation. As the investment level increases, additional costs arise from data collection, system maintenance, personnel training, node coordination, and system integration. Therefore, the marginal cost of blockchain investment increases with G . No transfer payment or fixed-cost-sharing arrangement is considered in the benchmark model.

Assumption 4. Following [71] showed that in an environment of insufficient information and high uncertainty, the risk perception and distrust of the subject can significantly affect its behavior decision and further weaken the acceptance intention of related products or technologies. Following that Reference [72], when blockchain is not adopted, information asymmetry prevents consumers from fully identifying the attributes and origin of agri-products. The corresponding demand function is $D(p, e) = (1 - x + re) - bp$, where $x > 0$ denotes the demand loss caused by consumer distrust, The parameter x captures the reduction in current demand caused by consumers' ex ante distrust of unverifiable product-origin information. It is distinct from g , which captures the post-transaction negative-review rate and affects the platform's expected monetary loss rather than current demand. Therefore, the effects of x and g are not counted repeatedly. $r > 0$ represents the utility coefficient of traceability effort, $b > 0$ is the price-sensitivity coefficient, and $p > 0$ is the market price. After the firm adopts blockchain, the demand function is $D(p, e, G) = (1 + re) - bp + hG$, the investment in blockchain has eliminated the level of consumer distrust. Where $h > 0$ represents blockchain trust gain coefficient, G represents blockchain investment level.

In this study, blockchain adoption is treated as a discrete governance-mode choice, whereas G represents the incremental investment made after the basic blockchain infrastructure and traceability mechanism have been established. Therefore, $G = 0$ does not indicate the absence of blockchain adoption; it indicates that no additional investment is made after the basic deployment. The demand difference between the two governance modes can thus be written as $D(p, e, G) - D(p, e) = x + hG$.

Here, x captures the institutional effect associated with the transition from the non-blockchain mode to the blockchain mode, while hG captures the marginal demand effect of incremental

blockchain investment. The model focuses on the equilibrium comparison between the two governance modes rather than on the gradual restoration of consumer trust during the blockchain deployment process.

Assumption 5. In this study, we assume that all members of the entire agri-product SC are rational decision-makers and hold a neutral attitude towards risks [70].

Assumption 6. The quadratic cost of blockchain investment reflects increasing marginal implementation costs arising from data collection, system maintenance, personnel training, node coordination, and system integration. In the benchmark demand function, the term hG represents the demand benefit generated by enhanced information verifiability and consumer trust. Specifically, blockchain investment does not generate additional traceability information itself but improves the credibility and accessibility of existing traceability information, thereby increasing consumers' willingness to purchase traceable products. The linear specification captures the first-order demand effect of blockchain investment within the equilibrium range considered in this study. Traceability effort e reflects the amount and completeness of traceability information, whereas blockchain investment G improves the verifiability of that information. Therefore, blockchain investment does not replace traceability effort itself but enhances the credibility and accessibility of the generated traceability information. Accordingly, e and G represent distinct mechanisms and enter the demand function separately. The benchmark model abstracts from several practical considerations, including investment saturation, implementation failure, interoperability risk, data-quality uncertainty, and the interaction between e and G . Incorporating these factors into a more comprehensive blockchain adoption framework provides a promising direction for future research.

All decision variables are subject to the following feasibility constraints:

$$a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 4kb < 0, \quad bc - a + ax + bg_0 l < 0, \quad 2bk - a^2 r^2 > 0.$$

Based on the above assumption, before and after the introduction of blockchain, the profit functions of different SC decision models are expressed as:

In the scenario without blockchain, the agricultural cooperative profit was π^m , live electric business platform profit was π^r , and the SC comprehensive profit was π^c :

$$\pi^m = (w - c)D - \frac{1}{2}ke^2, \quad (1)$$

$$\pi^r = (p - w)D - glD, \quad (2)$$

$$\pi^c = (p - c)D - \frac{1}{2}ke^2 - glD. \quad (3)$$

The term glD is an expected monetary loss rather than a demand-reduction term. The effect of consumers' pre-purchase distrust on demand has already been captured by x and is therefore not included again through g .

With blockchain, the agricultural cooperative profit was π^m , live electric business platform profit was π^r , and the SC comprehensive profit was π^c . However, the composition of the profit function has changed, and it is specifically expressed as follows:

$$\pi^m = (w - c)D - \frac{1}{2}ke^2 - \frac{1}{2}k_g G^2 - C_b, \quad (4)$$

$$\pi^r = (p - w)D, \quad (5)$$

$$\pi^c = (p - c)D - \frac{1}{2}ke^2 - \frac{1}{2}k_g G^2 - C_b. \quad (6)$$

Under the blockchain mode, product-origin and traceability information becomes verifiable. Therefore, the specific negative-review loss arising from unverifiable origin information is normalized to zero. This assumption does not imply that all types of negative reviews disappear; it only excludes the negative reviews associated with the information-verification problem examined in this paper. Traceability effort e remains relevant under blockchain because it reflects the cooperative's effort in collecting, maintaining, and presenting traceability information. Blockchain improves the verifiability of this information, whereas e determines its completeness and usefulness to consumers. Therefore, e continues to affect consumer utility and demand under the blockchain mode.

4. Model solution and analysis

The second-order conditions are satisfied in the admissible parameter region. Therefore, each player's optimization problem is strictly concave in its own decision variable, which guarantees a unique best response. By backward induction, the equilibrium of each sequential game is unique within the admissible interior region. The proof process can be found in Appendix A. All decision variables are subject to the following feasibility constraints:

$$2bk - 2abdlr - a^2r^2 - b^2d^2l^2 > 0, \quad -2bkk_g + a^2r^2k_g + bh^2k < 0.$$

For non-blockchain models, G is not included. Additionally, the results in the balance equation must be positive, and the equilibrium solution must satisfy the economic constraints corresponding to each model. Moreover, the relevant second-order conditions must also hold. The proof process can be found in Appendix A. Accordingly, the closed-form solutions derived in Sections 4.1 and 4.2 are interior solutions defined on the admissible parameter region satisfying these conditions. Under this region, the players' objective functions are strictly concave with respect to their respective decision variables, and the sequential games have unique interior equilibria. The closed-form solutions derived in this section are interior solutions defined within the admissible parameter region specified above. If an unconstrained solution violates any nonnegativity constraint, the corresponding constrained solution lies on the boundary. In particular, $e = 0$ when the unconstrained traceability effort is nonpositive, whereas $G = 0$ when the unconstrained blockchain investment is nonpositive. The equilibrium and comparative results reported below therefore apply to the admissible parameter region in which the interior solution is valid.

4.1. SC decisions before the introduction of blockchain

4.1.1. Agricultural cooperative-led decision-making model (AM model)

In the absence of blockchain technology, under the admissible parameter region defined above, the interior equilibrium solution of the AM model is as follows:

$$w_{AM} = \frac{a^2 cr^2 - 2ak - 2bck + 2akx + b^2 cd^2 l^2 + 2bg_0 kl + 2abcdlr}{a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 4kb}, \quad (7)$$

$$e_{AM} = \frac{(ar + bdl)(bc - a + ax + bg_0 l)}{a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 4kb}, \quad (8)$$

$$p_{AM} = \frac{a^2 cr^2 - 3ak - bck + 3akx + a^2 dlr + abd^2 l^2 + a^2 g_0 lr^2 - bg_0 kl - abd^2 l^2 x - a^2 dlr x + abd g_0 l^2 r + abcdlr}{a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 4kb}, \quad (9)$$

$$D_{AM} = \frac{bk(bc - a + ax + bg_0 l)}{a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 4kb}, \quad (10)$$

$$\pi_{AM}^m = -\frac{k(bc - a + ax + bg_0 l)^2}{2(a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 4kb)}, \quad (11)$$

$$\pi_{AM}^r = \frac{bk^2(bc - a + ax + bg_0 l)^2}{(a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 4kb)^2}, \quad (12)$$

$$\pi_{AM}^c = -\frac{k(bc - a + ax + bg_0 l)^2(a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 6kb)}{2(a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 4kb)^2}. \quad (13)$$

4.1.2. Live electric business platform-led decision-making (AR model)

In the absence of blockchain technology, under the admissible parameter region defined above, the interior equilibrium solution of the AR model is as follows:

$$m_{AR} = -\frac{a^3 r^2 x - a^3 r^2 + 2abk - 2b^2 ck - 2abkx + 2b^2 g_0 kl + a^2 bcr^2 - a^2 bg_0 lr^2 - 2a^2 bdlr + 2ab^2 cdlr + 2a^2 bdlrx}{2a^2 br^2 + 2dlab^2 r - 4kb^2}, \quad (14)$$

$$w_{AR} = \frac{2a^2 cr^2 - ak - 3bck + akx + bg_0 kl + 2abcdlr}{2a^2 r^2 + 2bdlar - 4bk}, \quad (15)$$

$$e_{AR} = \frac{ar(bc - a + ax + bg_0 l)}{2a^2 r^2 + 2bdlar - 4bk}, \quad (16)$$

$$\pi_{AM}^c = -\frac{k(bc - a + ax + bg_0 l)^2(a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 6kb)}{2(a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 4kb)^2}, \quad (17)$$

$$p_{AR} = \frac{a^3 r^2 - a^3 r^2 x - 3abk - b^2 ck + 3abkx - b^2 g_0 kl + a^2 bcr^2 + a^2 bg_0 lr^2 + 2a^2 bdlr - 2a^2 bdlrx}{2b(a^2 r^2 + bdlar - 2bk)}, \quad (18)$$

$$\pi_{AR}^m = \frac{k(2bk - a^2 r^2)(bc - a + ax + bg_0 l)^2}{8(a^2 r^2 + bdlar - 2bk)^2}, \quad (19)$$

$$\pi_{AR}^r = -\frac{k(bc - a + ax + bg_0 l)^2}{4a^2 r^2 + 4bdlar - 8bk}, \quad (20)$$

$$\pi_{AR}^c = -\frac{k(3a^2 r^2 + 2bdlar - 6bk)(bc - a + ax + bg_0 l)^2}{8(a^2 r^2 + bdlar - 2bk)^2}. \quad (21)$$

4.1.3. Centralized decision-making (AC model)

In the absence of blockchain, under the admissible parameter region defined above, the interior optimum of the AC model is as follows:

$$p_{AC} = \frac{a^2 cr^2 - ak - bck + akx + a^2 dlr + abd^2 l^2 + a^2 g_0 lr^2 - bg_0 kl - abd^2 l^2 x - a^2 dlr x + abd g_0 l^2 r + abcdlr}{a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 2kb}, \quad (22)$$

$$e_{AC} = \frac{(ar + bdl)(bc - a + ax + bg_0 l)}{a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 2kb}, \quad (23)$$

$$D_{AC} = \frac{bk(bc - a + ax + bg_0 l)}{a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 2kb}, \quad (24)$$

$$\pi_{AC}^c = -\frac{k(bc - a + ax + bg_0 l)^2}{2(a^2 r^2 + 2abdlr + b^2 d^2 l^2 - 2kb)}. \quad (25)$$

4.2. SC decisions when introducing blockchain

4.2.1. Agricultural cooperative-led decision-making model (BM model)

In the case of introducing blockchain, under the admissible parameter region defined above, the interior equilibrium solution of the BM model is as follows:

$$w_{BM} = -\frac{-ck_g a^2 r^2 + 2kk_g a - ckh^2 + 2bckk_g}{k_g a^2 r^2 + kh^2 - 4bkk_g}, \quad (26)$$

$$e_{BM} = -\frac{ak_g r(a-bc)}{k_g a^2 r^2 + kh^2 - 4bkk_g}, \quad (27)$$

$$G_{BM} = -\frac{hk(a-bc)}{k_g a^2 r^2 + kh^2 - 4bkk_g}, \quad (28)$$

$$G_{BM} = -\frac{-ck_g a^2 r^2 + 3kk_g a - ckh^2 + bckk_g}{k_g a^2 r^2 + kh^2 - 4bkk_g}, \quad (29)$$

$$D_{BM} = -\frac{bkk_g(a-bc)}{k_g a^2 r^2 + kh^2 - 4bkk_g}, \quad (30)$$

$$\pi_{BM}^m = -\frac{2C_b k_g a^2 r^2 + kk_g a^2 - 2kk_g abc + kk_g b^2 c^2 - 8C_b k k_g b + 2C_b kh^2}{2(k_g a^2 r^2 + kh^2 - 4bkk_g)}, \quad (31)$$

$$\pi_{BM}^r = \frac{bk^2 k_g^2 (a-bc)^2}{(k_g a^2 r^2 + kh^2 - 4bkk_g)^2}, \quad (32)$$

$$\pi_{BM}^c = \frac{2bk^2 k_g^2 (a-bc)^2 - (k_g a^2 r^2 + kh^2 - 4bkk_g) [2C_b k_g a^2 r^2 + kk_g (a-bc)^2 - 8C_b k k_g b + 2C_b kh^2]}{2(k_g a^2 r^2 + kh^2 - 4bkk_g)^2}. \quad (33)$$

4.2.2. Live electric business platform-led decision-making (BR model)

In the case of introducing blockchain, under the admissible parameter region defined above, the interior equilibrium solution of the BR model is as follows:

$$m_{BR} = \frac{a-bc}{2b}, \quad (34)$$

$$w_{BR} = -\frac{-2ck_g a^2 r^2 + kk_g a - 2ckh^2 + 3bckk_g}{2k_g a^2 r^2 + 2kh^2 - 4bkk_g}, \quad (35)$$

$$e_{BR} = -\frac{ak_g r\left(\frac{a}{2} - \frac{bc}{2}\right)}{k_g a^2 r^2 + kh^2 - 2bkk_g}, \quad (36)$$

$$G_{BR} = -\frac{hk(a-bc)}{2k_g a^2 r^2 + 2kh^2 - 4bkk_g}, \quad (37)$$

$$p_{BR} = \frac{k_g a^3 r^2 + akh^2 - bckh^2 - bkk_g a - b^2 ckk_g}{2b(k_g a^2 r^2 + kh^2 - 4bkk_g)}, \quad (38)$$

$$\pi_{BR}^m = -\frac{8C_b k_g a^2 r^2 + k k_g a^2 - 2k k_g abc + k k_g b^2 c^2 - 16C_b k k_g b + 8C_b k h^2}{8(k_g a^2 r^2 + k h^2 - 2b k k_g)}, \quad (39)$$

$$\pi_{BR}^r = -\frac{k k_g (a-bc)^2}{4k_g a^2 r^2 + 4k h^2 - 8b k k_g}, \quad (40)$$

$$= -\frac{8C_b k_g a^2 r^2 + 3k k_g a^2 - 6k k_g abc + 3k k_g b^2 c^2 - 16C_b k k_g b + 8C_b k h^2}{8(k_g a^2 r^2 + k h^2 - 2b k k_g)}. \quad (41)$$

4.2.3. Centralized decision-making (BC model)

In the case of introducing blockchain, under the admissible parameter region defined above, the interior optimum of the BC model is as follows:

$$e_{BC} = -\frac{a k_g r(a-bc)}{k_g a^2 r^2 + k h^2 - 2b k k_g}, \quad (42)$$

$$p_{BC} = -\frac{-c k_g a^2 r^2 + k k_g a - c k h^2 + b c k k_g}{k_g a^2 r^2 + k h^2 - 2b k k_g}, \quad (43)$$

$$G_{BC} = -\frac{h k(a-bc)}{k_g a^2 r^2 + k h^2 - 2b k k_g}, \quad (44)$$

$$D_{BC} = -\frac{b k k_g(a-bc)}{k_g a^2 r^2 + k h^2 - 2b k k_g}, \quad (45)$$

$$\pi_{BC}^c = -\frac{2C_b k_g a^2 r^2 + k k_g a^2 - 2k k_g abc + k k_g b^2 c^2 - 4C_b k k_g b + 2C_b k h^2}{2(k_g a^2 r^2 + k h^2 - 2b k k_g)}. \quad (46)$$

4.3. Equilibrium analysis

4.3.1. Comparative analysis of AM model, AR model, and AC model

Theorem 1. $\pi_{AM}^c < \pi_{AR}^c < \pi_{AC}^c$, $w_{AM} > w_{AR}$, $e_{AM} < e_{AR} < e_{AC}$, $\pi_{AM}^m > \pi_{AM}^r$, $\pi_{AR}^m < \pi_{AR}^r$.

Proof.

$$\pi_{AR}^c - \pi_{AM}^c = \frac{k k_g (k_g a^2 r^2 + k h^2)(a-bc)^2 (k_g a^2 r^2 + k h^2 - 8b k k_g)}{8(k_g a^2 r^2 + k h^2 - 2b k k_g)(k_g a^2 r^2 + k h^2 - 4b k k_g)^2} > 0,$$

$$\pi_{AR}^c - \pi_{AC}^c = \frac{k k_g (a-bc)^2}{8(k_g a^2 r^2 + k h^2 - 2b k k_g)} < 0,$$

$$\frac{w_{AM}}{w_{AR}} = \frac{(2a^2r^2 + 2bdlar - 4bk)(a^2cr^2 - 2ak - 2bck + 2akx + b^2cd^2l^2 + 2bg_0kl + 2abcdlr)}{(a^2r^2 + 2abdldr + b^2d^2l^2 - 4kb)(2a^2cr^2 - ak - 3bck + akx + bg_0kl + 2abcdlr)} > 1,$$

$$e_{AR} - e_{AM} = \frac{(ar + bdl)(2a^2r^2 + 2bdlar - 4bk)}{ar(a^2r^2 + 2abdldr + b^2d^2l^2 - 4kb)} > 0,$$

$$\frac{e_{AC}}{e_{AR}} = \frac{a^2r^2 + 2abdldr + b^2d^2l^2 - 4kb}{a^2r^2 + 2abdldr + b^2d^2l^2 - 2kb} > 1,$$

$$\frac{\pi_{AM}^m}{\pi_{AM}^r} = -\frac{8(a^2r^2 + bdlar - 2bk)^2}{(2bk - a^2r^2)(2a^2r^2 + 4abdldr + 2b^2d^2l^2 - 8kb)} > 1,$$

$$\frac{\pi_{AR}^m}{\pi_{AR}^r} = -\frac{bk(4a^2r^2 + 4bdlar - 8bk)}{(a^2r^2 + 2abdldr + b^2d^2l^2 - 4kb)^2} < 1.$$

Remark 1: The wholesale price under the manufacturer-led model is higher than that under the retailer-led model. The reason for this is as follows: When the manufacturer acts as the leader, it can utilize the priority pricing power to set the wholesale price at a higher level to capture channel profits; while in the retailer-led structure, the retailer, by prioritizing the formulation of retail prices, inversely compresses the pricing space of the manufacturer, forcing the manufacturer to accept a lower wholesale price to maintain cooperation.

Remark 2: The total profit of the SC, on the other hand, is ranked in the opposite order $\pi_{AM}^c < \pi_{AR}^c < \pi_{AC}^c$. Under the manufacturer-led structure, retailers independently set prices based on the given wholesale price and tend to increase retail prices to obtain marginal profits, resulting in the most severe price distortion. In the retailer-led structure, although retailers have the initiative advantage, they need to consider the inhibitory effect of high prices on demand and the retail prices are slightly lower than in the former. Centralized decision-making eliminates the double marginal effect, with the lowest retail prices and the highest total profits. In decentralized decision-making, the total profits of the retailer-led structure are higher than those of the manufacturer-led structure. This result can be attributed to the characteristics of agricultural product SC, where consumer trust and demand uncertainty play important roles in SC performance. Compared with manufacturers, retailers are closer to consumers and have better access to market feedback and consumer preferences. Therefore, when retailers dominate decision-making, traceability investment and pricing decisions can better respond to consumer trust requirements, thereby improving demand performance and coordination efficiency.

Remark 3: Under decentralized decision-making, the profits of leaders are always higher than those of followers. This result is in line with the initiative advantage feature of the Stackelberg game, that is, the leader can influence the follower's reaction function through priority decision-making and seize greater channel profits. However, from the absolute profit level, the profits of all parties under decentralized decision-making are lower than the distributable profit share in centralized decision-making, indicating that the essence of the power structure competition is essentially a zero-sum game within the channel, while centralized decision-making is the Pareto optimal path for maximizing the overall interests of the SC.

4.3.2. The impact of consumer distrust on SC decisions

Theorem 2. $\frac{\partial w_{AM}}{\partial x} < 0$, $\frac{\partial e_{AM}}{\partial x} < 0$, $\frac{\partial p_{AM}}{\partial x} < 0$, $\frac{\partial \pi_{AM}^m}{\partial x} < 0$, $\frac{\partial \pi_{AM}^r}{\partial x} < 0$, $\frac{\partial \pi_{AM}^c}{\partial x} < 0$, $\frac{\partial w_{AR}}{\partial x} < 0$, $\frac{\partial e_{AR}}{\partial x} < 0$, $\frac{\partial p_{AR}}{\partial x} < 0$, $\frac{\partial \pi_{AR}^m}{\partial x} < 0$, $\frac{\partial \pi_{AR}^r}{\partial x} < 0$, $\frac{\partial \pi_{AR}^c}{\partial x} < 0$, $\frac{\partial p_{AC}}{\partial x} < 0$, $\frac{\partial e_{AC}}{\partial x} < 0$, $\frac{\partial \pi^c}{\partial x} < 0$.

Proof.

$$\frac{\partial w_{AM}}{\partial x} = \frac{2ak}{a^2 r^2 + 2abd lr + b^2 d^2 l^2 - 4kb} < 0,$$

$$\frac{\partial e_{AM}}{\partial x} = \frac{a(ar + bdl)}{a^2 r^2 + 2abd lr + b^2 d^2 l^2 - 4kb} < 0,$$

$$\frac{\partial p_{AM}}{\partial x} = \frac{a(3k - bd^2 l^2) - a^2 dlr}{a^2 r^2 + 2abd lr + b^2 d^2 l^2 - 4kb} < 0,$$

$$\frac{\partial \pi_{AM}^m}{\partial x} = \frac{ak(a - ax) - abk(c + g_0 l)}{a^2 r^2 + 2abd lr + b^2 d^2 l^2 - 4kb} < 0,$$

$$\frac{\partial \pi_{AM}^r}{\partial x} = \frac{2a^2 bk^2(x - 1) + 2ab^2 k^2(c + g_0 l)}{(a^2 r^2 + 2abd lr + b^2 d^2 l^2 - 4kb)^2} < 0,$$

$$\frac{\partial \pi_{AM}^c}{\partial x} = -\frac{ak(bc - a + ax + bg_0 l)(a^2 r^2 + 2abd lr + b^2 d^2 l^2 - 6kb)}{(a^2 r^2 + 2abd lr + b^2 d^2 l^2 - 4kb)^2} < 0,$$

$$\frac{\partial w_{AR}}{\partial x} = -\frac{ak}{2(b(2k - adlr) - a^2 r^2)} < 0,$$

$$\frac{\partial e_{AR}}{\partial x} = -\frac{a^2 r}{2(b(2k - adlr) - a^2 r^2)} < 0,$$

$$\frac{\partial p_{AR}}{\partial x} = -\frac{\frac{a^3 r^2}{2} - \frac{ab(3k - 2adlr)}{2}}{b(a^2 r^2 + bdlar - 2bk)} < 0,$$

$$\frac{\partial \pi_{AR}^m}{\partial x} = \frac{ak(2bk - a^2 r^2)(bc - a + ax + bg_0 l)}{4(a^2 r^2 + bdlar - 2bk)^2} < 0,$$

$$\frac{\partial \pi_{AR}^r}{\partial x} = -\frac{ak(bc - a + ax + bg_0 l)}{2(a^2 r^2 + bdlar - 2bk)} < 0,$$

$$\frac{\partial \pi_{AR}^c}{\partial x} = -\frac{ak(3a^2 r^2 + 2bdlar - 6bk)(bc - a + ax + bg_0 l)}{4(a^2 r^2 + bdlar - 2bk)^2} < 0,$$

$$\frac{\partial p_{AC}}{\partial x} = \frac{a(k - bd^2 l^2) - a^2 dlr}{a^2 r^2 + 2abd lr + b^2 d^2 l^2 - 2kb} < 0,$$

$$\frac{\partial e_{AC}}{\partial x} = \frac{a(ar + bdl)}{a^2 r^2 - b(2k - 2adlr) + b^2 d^2 l^2} < 0,$$

$$\frac{\partial \pi_{AC}^c}{\partial x} = \frac{ak(a-ax) - abk(c+g_0l)}{a^2r^2 + 2abd lr + b^2d^2l^2 - 2kb} < 0.$$

Remark 4: When the level of consumer distrust increases, the market's basic demand declines, thereby weakening the expected profits of SC members. According to the demand function, the rise in consumer distrust directly suppresses consumers' purchasing intentions, thereby compressing market demand. In this situation, manufacturers will reduce their traceability investment to avoid high costs and retailers will mitigate the adverse impact of shrinking demand by lowering prices. At the same time, wholesale prices also decrease to adapt to the contraction of terminal market demand. Therefore, increased consumer distrust will inhibit various SC decision variables through the demand transmission mechanism, making them all negatively correlated with the level of consumer distrust.

4.3.3. Comparative analysis of BM model, BR model, and BC model

Theorem 3. $\pi_{BM}^c < \pi_{BR}^c < \pi_{BC}^c$, $w_{BM} > w_{AR}$, $e_{BM} < e_{BR} < e_{BC}$, $p_{BM} > p_{BR} > p_{BC}$, $\pi_{BM}^m > \pi_{BM}^r$, $\pi_{BR}^m < \pi_{BR}^r$, $G_{BC} > G_{BR} > G_{BM}$.

Proof.

$$\pi_{BR}^c - \pi_{BM}^c = \frac{kk_g(k_g a^2 r^2 + kh^2)(a-bc)^2(k_g a^2 r^2 + kh^2 - 8bkk_g)}{8(k_g a^2 r^2 + kh^2 - 2bkk_g)(k_g a^2 r^2 + kh^2 - 4bkk_g)} > 0,$$

$$\pi_{BR}^c - \pi_{BC}^c = \frac{kk_g(a-bc)^2}{8(k_g a^2 r^2 + kh^2 - 2bkk_g)} < 0,$$

$$\frac{w_{BM}}{w_{BR}} = \frac{(k_g a^2 r^2 + kh^2 - 4bkk_g)(-2ck_g a^2 r^2 + kk_g a - 2ckh^2 + 3bckk_g)}{(2k_g a^2 r^2 + 2kh^2 - 4bkk_g)(-ck_g a^2 r^2 + 2kk_g a - ckh^2 + 2bckk_g)} > 1,$$

$$e_{BM} - e_{BR} = \frac{k_g a^2 r^2 + kh^2 - 4bkk_g}{2k_g a^2 r^2 + 2kh^2 - 4bkk_g} < 0, \frac{e_{BR}}{e_{BC}} = \frac{1}{2},$$

$$G_{BM} - G_{BR} = \frac{k_g a^2 r^2 + kh^2 - 4bkk_g}{2k_g a^2 r^2 + 2kh^2 - 4bkk_g} < 0, \frac{G_{BR}}{G_{BC}} = \frac{1}{2},$$

$$\frac{\pi_{BR}^m}{\pi_{BR}^r} = -\frac{(k_g a^2 r^2 + kh^2 - 4bkk_g)^2}{bkk_g(4k_g a^2 r^2 + 4kh^2 - 8bkk_g)} < 1,$$

$$\pi_{BM}^r - \pi_{BM}^m = \frac{kk_g(a-bc)^2(3k_g a^2 r^2 + 3kh^2 - 4bkk_g)}{8(a^4 k_g^2 r^4 - 6a^2 bkk_g^2 r^2 + 2a^2 h^2 k k_g r^2 + 8b^2 k^2 k_g^2 - 6bh^2 k^2 k_g + h^4 k^2)} < 0.$$

Remark 5: After the introduction of blockchain, the wholesale prices in the decentralized decision-making model led by cooperatives are still higher than those in the model dominated by e-commerce platforms. This is because after the introduction of blockchain, cooperatives can enhance consumer trust through a transparent traceability system, thereby maintaining their pricing power in the SC. Although the model dominated by e-commerce platforms has greater bargaining power in decentralized decision-making, the introduction of blockchain technology has strengthened the cooperatives' control over product traceability and reduced the uncertainty of traceability costs. As a result, cooperatives can relatively stably maintain higher wholesale prices.

Remark 6: After the introduction of blockchain, the traceability level under centralized decision-making is the highest, followed by decentralized decision-making under the dominance of e-commerce platforms, and the lowest under decentralized decision-making under the dominance of cooperatives. This conclusion indicates that the introduction of blockchain technology effectively enhances the traceability incentives for all parties in the SC, especially in the centralized decision-making model, where the traceability benefits are fully internalized, improving the overall traceability level. In the decentralized decision-making model, due to the incomplete coordination of the distribution of interests between the platform and the manufacturer, the traceability level is relatively low, but the platform-dominated model is still slightly higher than the manufacturer-dominated model.

Remark 7: The higher wholesale price under the manufacturer's dominance increases the marginal cost of retailers, and the retail price is the highest; under the retailer's dominance, the wholesale price is lower, leaving room for retail price reduction; centralized decision-making eliminates double markup, and the price is the lowest. The total profit ranking indicates that decentralization leads to efficiency losses, and centralized decision-making remains Pareto optimal. Moreover, under decentralized decision-making, the retailer-led model achieves higher total SC profit than the cooperative-led model. This result is mainly because live-streaming e-commerce platforms are closer to consumers and can obtain more direct information about consumer preferences, market demand, and trust requirements. After the introduction of blockchain technology, transparent traceability information further strengthens the ability of platforms to identify and transmit consumer trust signals, allowing pricing and traceability decisions to better match market demand. Therefore, although cooperative-led decision-making has a first-mover advantage, the retailer-led structure can achieve relatively higher coordination efficiency by utilizing consumer-side information advantages. In terms of member profits, the leader's profit is always higher than that of the followers, proving the dominant position of the leader in the SC game.

4.3.4. The impact of the utility of traceability effort on SC decision-making

Theorem 4. $\frac{\partial w_{BM}}{\partial r} > 0$, $\frac{\partial p_{BM}}{\partial r} > 0$, $\frac{\partial e_{BM}}{\partial r} > 0$, $\frac{\partial G_{BM}}{\partial r} > 0$, $\frac{\partial \pi'_{BM}}{\partial r} > 0$, $\frac{\partial \pi^m_{BM}}{\partial r} > 0$, $\frac{\partial \pi^c_{BM}}{\partial r} > 0$, $\frac{\partial w_{BR}}{\partial r} > 0$, $\frac{\partial p_{BR}}{\partial r} > 0$, $\frac{\partial e_{BR}}{\partial r} > 0$, $\frac{\partial G_{BR}}{\partial r} > 0$, $\frac{\partial \pi'_{BR}}{\partial r} > 0$, $\frac{\partial \pi^m_{BR}}{\partial r} > 0$, $\frac{\partial \pi^c_{BR}}{\partial r} > 0$, $\frac{\partial p_{BC}}{\partial r} > 0$, $\frac{\partial e_{BC}}{\partial r} > 0$, $\frac{\partial G_{BC}}{\partial r} > 0$, $\frac{\partial \pi^c_{BC}}{\partial r} > 0$.

Proof.

$$\begin{aligned}\frac{\partial w_{BM}}{\partial r} &= \frac{4a^2 k k_g^2 r(a-bc)}{(k_g a^2 r^2 + k h^2 - 4b k k_g)^2} > 0, \\ \frac{\partial p_{BM}}{\partial r} &= \frac{6a^2 k k_g^2 r(a-bc)}{(k_g a^2 r^2 + k h^2 - 4b k k_g)^2} > 0, \\ \frac{\partial e_{BM}}{\partial r} &= \frac{a k_g (a-bc)(k_g a^2 r^2 - k h^2 + 4b k k_g)}{(k_g a^2 r^2 + k h^2 - 4b k k_g)^2} > 0, \\ \frac{\partial G_{BM}}{\partial r} &= \frac{2a^2 h k k_g r(a-bc)}{(k_g a^2 r^2 + k h^2 - 4b k k_g)^2} > 0,\end{aligned}$$

$$\begin{aligned}
\frac{\partial \pi_{BM}^r}{\partial r} &= -\frac{4a^2 b k_g^2 k_g^3 r(a-bc)^2}{(k_g a^2 r^2 + k h^2 - 4b k k_g)^3} > 0, \\
\frac{\partial \pi_{BM}^m}{\partial r} &= \frac{a^2 k k_g^2 r(a-bc)^2}{(k_g a^2 r^2 + k h^2 - 4b k k_g)^2} > 0, \\
\frac{\partial \pi_{BM}^c}{\partial r} &= \frac{a^2 k k_g^2 r(a-bc)^2 (k_g a^2 r^2 + k h^2 - 8b k k_g)}{(k_g a^2 r^2 + k h^2 - 4b k k_g)^3} > 0, \\
\frac{\partial w_{BR}}{\partial r} &= \frac{a^2 k k_g^2 r(a-bc)}{(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0, \\
\frac{\partial p_{BR}}{\partial r} &= \frac{a^2 k k_g^2 r(a-bc)}{(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0, \\
\frac{\partial e_{BR}}{\partial r} &= \frac{a k_g (a-bc) (k_g a^2 r^2 - k h^2 + 2b k k_g)}{2(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0, \\
\frac{\partial G_{BR}}{\partial r} &= \frac{a^2 h k k_g r(a-bc)}{(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0, \\
\frac{\partial \pi_{BR}^c}{\partial r} &= \frac{a^2 k k_g^2 r(a-bc)^2}{2(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0, \\
\frac{\partial \pi_{BR}^m}{\partial r} &= \frac{a^2 k k_g^2 r(a-bc)^2}{4(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0, \\
\frac{\partial \pi_{BR}^c}{\partial r} &= \frac{3a^2 k k_g^2 r(a-bc)^2}{4(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0, \\
\frac{\partial p_{BC}}{\partial r} &= \frac{2a^2 k k_g^2 r(a-bc)}{(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0, \\
\frac{\partial e_{BC}}{\partial r} &= \frac{a k_g (a-bc) (k_g a^2 r^2 - k h^2 + 2b k k_g)}{(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0, \\
\frac{\partial G_{BC}}{\partial r} &= \frac{2a^2 h k k_g r(a-bc)}{(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0, \\
\frac{\partial \pi_{BC}^c}{\partial r} &= \frac{a^2 k k_g^2 r(a-bc)^2}{(k_g a^2 r^2 + k h^2 - 2b k k_g)^2} > 0.
\end{aligned}$$

Remark 8. After the introduction of blockchain, the utility of the traceability effort remains positively correlated with various decision variables. This phenomenon demonstrates the enhancing effect of blockchain technology on SC transparency and trust. Specifically, blockchain provides reliable traceability information, reducing consumers' distrust of product origins, thereby increasing the marginal benefit of traceability. In this context, members of the SC enhance consumer trust by increasing traceability investment, which in turn drives up market demand and prices. Therefore, the

introduction of blockchain not only optimizes the traceability level but also creates more value for the SC by enhancing market trust. Overall, the improvement of the traceability level becomes an important means to enhance market competitiveness and profits.

4.3.5. The impact of trust gain coefficient on SC decision-making

Theorem 5. $\frac{\partial w_{BM}}{\partial h} > 0$, $\frac{\partial p_{BM}}{\partial h} > 0$, $\frac{\partial e_{BM}}{\partial h} > 0$, $\frac{\partial G_{BM}}{\partial h} > 0$, $\frac{\partial \pi_{BM}^r}{\partial h} > 0$, $\frac{\partial \pi_{BM}^m}{\partial h} > 0$, $\frac{\partial \pi_{BM}^c}{\partial h} > 0$, $\frac{\partial w_{BR}}{\partial h} > 0$, $\frac{\partial p_{BR}}{\partial h} > 0$, $\frac{\partial e_{BR}}{\partial h} > 0$, $\frac{\partial G_{BR}}{\partial h} > 0$, $\frac{\partial \pi_{BR}^m}{\partial h} > 0$, $\frac{\partial \pi_{BR}^c}{\partial h} > 0$, $\frac{\partial p_{BC}}{\partial h} > 0$, $\frac{\partial e_{BC}}{\partial h} > 0$, $\frac{\partial G_{BC}}{\partial h} > 0$, $\frac{\partial \pi_{BC}^c}{\partial h} > 0$.

Proof.

$$\begin{aligned}\frac{\partial w_{BM}}{\partial h} &= \frac{4hk^2k_g(a-bc)}{(k_g a^2 r^2 + kh^2 - 4bkk_g)^2} > 0, \\ \frac{\partial p_{BM}}{\partial h} &= \frac{6hk^2k_g(a-bc)}{(k_g a^2 r^2 + kh^2 - 4bkk_g)^2} > 0, \\ \frac{\partial e_{BM}}{\partial h} &= \frac{2ahkk_g r(a-bc)}{(k_g a^2 r^2 + kh^2 - 4bkk_g)^2} > 0, \\ \frac{\partial G_{BM}}{\partial h} &= \frac{k(a-bc)(-k_g a^2 r^2 + kh^2 + 4bkk_g)}{(k_g a^2 r^2 + kh^2 - 4bkk_g)^2} > 0, \\ \frac{\partial \pi_{BM}^r}{\partial h} &= -\frac{4bhk^3k_g^2(a-bc)^2}{(k_g a^2 r^2 + kh^2 - 4bkk_g)^3} > 0, \\ \frac{\partial \pi_{BM}^m}{\partial h} &= \frac{hk^2k_g(a-bc)^2}{(k_g a^2 r^2 + kh^2 - 4bkk_g)^2} > 0, \\ \frac{\partial \pi_{BM}^c}{\partial h} &= \frac{hk^2k_g(a-bc)^2(k_g a^2 r^2 + kh^2 - 8bkk_g)}{(k_g a^2 r^2 + kh^2 - 4bkk_g)^3} > 0, \\ \frac{\partial w_{BR}}{\partial h} &= \frac{hk^2k_g(a-bc)}{(k_g a^2 r^2 + kh^2 - 2bkk_g)^2} > 0, \\ \frac{\partial p_{BR}}{\partial h} &= \frac{hk^2k_g(a-bc)}{(k_g a^2 r^2 + kh^2 - 2bkk_g)^2} > 0, \\ \frac{\partial e_{BR}}{\partial h} &= \frac{2ahkk_g r\left(\frac{a}{2} - \frac{bc}{2}\right)}{(k_g a^2 r^2 + kh^2 - 2bkk_g)^2} > 0, \\ \frac{\partial G_{BR}}{\partial h} &= \frac{k(a-bc)(-k_g a^2 r^2 + kh^2 + 2bkk_g)}{2(k_g a^2 r^2 + kh^2 - 2bkk_g)^2} > 0,\end{aligned}$$

$$\begin{aligned}
\frac{\partial \pi_{BR}^r}{\partial h} &= \frac{hk^2k_g(a-bc)^2}{2(k_ga^2r^2+kh^2-2bkk_g)^2} > 0, \\
\frac{\partial \pi_{BR}^m}{\partial h} &= \frac{hk^2k_g(a-bc)^2}{4(k_ga^2r^2+kh^2-2bkk_g)^2} > 0, \\
\frac{\partial \pi_{BR}^c}{\partial h} &= \frac{3hk^2k_g(a-bc)^2}{4(k_ga^2r^2+kh^2-2bkk_g)^2} > 0, \\
\frac{\partial p_{BC}}{\partial h} &= \frac{2hk^2k_g(a-bc)}{(k_ga^2r^2+kh^2-2bkk_g)^2} > 0, \\
\frac{\partial e_{BC}}{\partial h} &= \frac{2ahkk_g r(a-bc)}{(k_ga^2r^2+kh^2-2bkk_g)^2} > 0, \\
\frac{\partial G_{BC}}{\partial h} &= \frac{k(a-bc)(-k_ga^2r^2+kh^2+2bkk_g)}{(k_ga^2r^2+kh^2-2bkk_g)^2} > 0, \\
\frac{\partial \pi_{BC}^c}{\partial h} &= \frac{hk^2k_g(a-bc)^2}{(k_ga^2r^2+kh^2-2bkk_g)^2} > 0.
\end{aligned}$$

Remark 9: After the introduction of blockchain, the coefficient of consumer trust gain is positively correlated with all decision variables. This indicates that the introduction of blockchain technology effectively enhances the transparency of the SC and consumer trust. With the support of blockchain, consumers' trust in the product origin is strengthened, which in turn promotes positive adjustments in decision variables, such as traceability level, price, demand, and profit. Specifically, as the trust gain coefficient increases, all parties in the SC are more inclined to increase traceability investment, improve product quality assurance, and promote demand growth through appropriate pricing. The transparent mechanism of blockchain enables consumers to be more willing to pay for traceability costs, thereby creating more value for the entire SC. Therefore, the improvement of the trust gain coefficient, driven by blockchain, becomes an important factor in promoting SC optimization and market efficiency.

4.3.6. Blockchain adoption decision and individual rationality

The equilibrium solutions derived above are conditional on the selected governance mode. To determine whether blockchain adoption is economically feasible for the agricultural cooperative, its optimized net profit under the blockchain mode is compared with its optimized profit under the non-blockchain mode. Let π^{m*} denote the cooperative's optimized profit without blockchain and let π_B^{m*} denote its optimized operating profit under blockchain before deducting the fixed deployment cost. The cooperative adopts blockchain if

$$\pi_B^{m*} - C_b \geq \pi^{m*}.$$

Equivalently, define the maximum acceptable fixed deployment cost as

$$C_b^* = \pi_B^{m*} - \pi^{m*}.$$

Blockchain adoption is economically feasible when $C_b \leq C_b^*$. When $C_b > C_b^*$, the cooperative prefers the non-blockchain mode. If $C_b^* \leq 0$, blockchain does not generate an operating-profit advantage over the non-blockchain mode, and the cooperative does not adopt blockchain when $C_b > 0$.

To distinguish individual rationality from overall SC performance, the profit changes of the agricultural cooperative, the live electric business platform, and the SC are respectively given by

$$\Delta\pi^m = \pi_B^{m*} - C_b - \pi^{m*},$$

$$\Delta\pi^r = \pi_B^{r*} - \pi^{r*},$$

$$\Delta\pi^c = \pi_B^{c*} - C_b - \pi^{c*}.$$

The individual participation constraint of the agricultural cooperative requires $\Delta\pi^m \geq 0$. A positive $\Delta\pi^c$ alone does not guarantee blockchain adoption because the SC may benefit while the agricultural cooperative, as the investing party, suffers a profit loss. If $\Delta\pi^c > 0$ and $\Delta\pi^m < 0$, unilateral blockchain adoption by the cooperative is not privately optimal. In this case, cost sharing or transfer payments between the agricultural cooperative and the live electric business platform are required to make blockchain adoption acceptable to both parties.

Since this study focuses on the equilibrium comparison between blockchain and non-blockchain regimes, the derived condition characterizes the economic feasibility of blockchain adoption under a given market environment rather than the dynamic evolution of adoption decisions.

4.4. Comparison with the closest related models

To isolate the contribution of this paper, we compare our model with the three closest studies identified in Table 1.

Degeneration to Reference [57]. In their model, the manufacturer bears the traceability cost and the demand function is $q = a - bp + \beta t$, with government subsidy g . They examine traceability decisions under different power structures, but do not consider blockchain, consumer distrust, or negative review losses. If we set $G = 0$ (no blockchain investment) and $x = 0$ (no consumer distrust), our models reduce to their framework. Our extensions yield three new results: (1) the blockchain investment level G is endogenized as a continuous decision variable, with a derived threshold condition for profitable adoption; (2) consumer distrust x and negative review loss gID are explicitly modeled, revealing two distinct channels through which distrust suppresses SC performance; and (3) blockchain adoption can fully offset the negative impact of consumer distrust on SC profit—a result not obtainable from their model.

Degeneration to Zhao et al. (2025) Reference [66]. They consider the loss-reduction and premium effects of smart agriculture technology under three power structures but treat technology adoption as a discrete choice (adopt or not) and do not model consumer distrust. If we replace blockchain with smart agriculture technology, treat G as fixed rather than optimized, and set $x = 0$, our model reduces to theirs. Our contribution lies in: (1) endogenizing technology investment G as a continuous variable, revealing that the optimal investment level follows the ranking $G_{BM} < G_{BR} < G_{BC}$; (2) It is confirmed that the trust-enhancing effect of blockchain is strongest under centralized power structures, a conclusion that cannot be derived from the study's model.

Degeneration to Reference [44]. They use differential game theory to study the impact of blockchain on consumer trust in an e-commerce closed-loop supply chain but consider only a single power structure (platform-led). If we isolate our retailer-led model and set $h=0$ (no trust gain) and $g/D=0$ (no negative review loss), our model reduces to theirs. Our extension provides the following: (1) a systematic comparison across three power structures, showing that centralized decision-making yields the highest blockchain investment level and (2) it is found that the profit-enhancing effect of blockchain applications is most pronounced under centralized power structures, thereby complementing the underexplored research dimension of power structures.

In summary, none of the above results can be derived from the limiting cases of previous models. This confirms that our contributions are novel and non-trivial.

5. Numerical illustration

This section provides numerical illustrations to complement the analytical results derived in Section 4. The purpose is to visualize the comparative statics and parameter effects rather than to provide an empirical case study. Section 4 separately analyzed the specific situations of SC decisions under three heterogeneous power structures in the cases of not introducing blockchain and introducing blockchain. Based on heterogeneous power structures, this chapter further considers three SC decision models with the introduction of blockchain technology. Through comparative analysis, it examines the conditions under which blockchain adoption improves supply chain decisions and performance. Numerical simulations are then used to compare the equilibrium outcomes before and after blockchain adoption under different power structures. The research content of this chapter is as follows:

(1) Based on the aforementioned equilibrium analysis results, compare the optimal pricing, traceability level, and profits of SC members under the two scenarios of not introducing blockchain and introducing blockchain.

(2) Further examine the critical threshold of the blockchain trust gain coefficient, analyze the direction and degree of the impact of this coefficient on SC profits before and after the introduction of blockchain technology, and identify the parameter boundary conditions for achieving improved benefits through blockchain adoption.

5.1. Analysis of SC decisions before the introduction of blockchain

The numerical analysis in this section serves three purposes. First, it verifies the feasibility of all derived equilibrium solutions by confirming that the parameter combinations satisfy the model constraints. Second, it visualizes the comparative statics results established in Section 4.3, illustrating the monotonic relationships between key parameters and decision variables. Third, it quantifies the magnitude of performance improvements brought by blockchain adoption and centralized decision-making, providing managerial insights for agri-product supply chain practitioners. Due to the difficulty of obtaining proprietary operational data from agricultural cooperatives and live-streaming e-commerce platforms, the numerical examples employ hypothetical parameter values calibrated to reflect realistic proportional relationships rather than exact empirical magnitudes. This approach is consistent with the analytical modeling convention in supply chain game-theoretic research, where the primary contribution lies in revealing directional relationships and mechanism design rather than providing point predictions.

In this section, before the introduction of blockchain technology, the impact of consumers' lack of trust in the source of products on the decisions and profits of each member in the agri-product SC under heterogeneous power structures was discussed. Refer to Reference [73], and based on the actual situation of this article, the specific parameter settings are as shown in the Table 3.

Table 3. Parameter assignment table before the introduction of blockchain.

Parameter	a	b	c	r	d	l	g_0	k
Value	100	1	10	0.1	0.1	0.5	0.1	400

Notes: Parameter values are selected based on the characteristics of a typical agri-product e-commerce supply chain in China. The parameter settings are consistent with the economic meanings described in Table 3 and satisfy all feasibility constraints, including $p > w > c > 0$, $e > 0$, positive profits, and non-zero denominators.

Based on the parameter values in Table 3 and the equilibrium solutions derived in Section 4.1.1, we obtain the following numerical results under the AM model with $x = 0.1$. Table 4 reports the equilibrium values and verifies that all feasibility constraints are satisfied.

Table 4. Equilibrium solutions and feasibility verification under three power structures (AM, AR, and AC) with $x = 0.1$.

Category	Variable	AM Model	AR Model	AC Model
Decision variables	w	52.665	32.859	
	e	0.536	0.571	1.149
	p	74.026	72.855	55.751
	D	21.334	22.859	45.751
Profit variables	π^m	852.837	457.224	
	π^r	455.150	913.795	
	π^c	1307.987	1371.020	1828.905
Feasibility check	$p > w > c > 0$	√	√	√
	$e > 0$	√	√	√

The degree of consumers' distrust in the source of products has the following impact on the relevant decisions and profits of each member in the SC:

When blockchain was not introduced, under three heterogeneous power structures, as the degree of consumers' distrust in the product origin increased, the wholesale prices of agri-products, retail prices, and the level of traceability all decreased. This was because as the degree of consumers' distrust in the product origin rose, the demand for agri-products by consumers decreased. Both manufacturers and retailers would lower prices to enhance competitiveness and would also reduce investment in agri-product traceability, thereby resulting in a low level of traceability. When blockchain was not introduced, the optimal pricing strategy for the agri-product SC satisfied the following relationship:

(1) As shown in Figure 3, there is $w_{AM} > w_{AR}$. At this time, the wholesale price under the leadership of the agri-product cooperative is the highest.

(2) As shown in Figure 4, there is $p_{AM} > p_{AR} > p_{AC}$. At this time, the market price under the leadership of the agri-product cooperative is the highest.

(3) As shown in Figure 5, there is $e_{AM} < e_{AR} < e_{AC}$. At this time, the agri-product traceability level under the centralized decision-making model is the highest.

(4) As shown in Figure 6, there is $\pi_{AM}^c < \pi_{AR}^c < \pi_{AC}^c$, $\pi_{AM}^m > \pi_{AR}^m$, $\pi_{AR}^m < \pi_{AR}^r$.

This indicates that centralized decision-making yields the highest profits, and in the SC, the profit of the leading party is higher than that of the followers. The increase in consumer distrust directly suppresses consumer purchasing intentions, leading to a contraction in market demand. Retailers are forced to lower retail prices to stabilize sales, and wholesale prices subsequently decline. The decline in demand simultaneously weakens the marginal return of unit traceability investment, and the optimal traceability level of cooperatives decreases. These adjustments further compress the marginal profit space. The total profits of manufacturers, retailers, and the SC all show a downward trend, indicating that the intensification of distrust systematically erodes the overall performance of the SC. This also conforms to the conclusion of the previous equilibrium analysis.

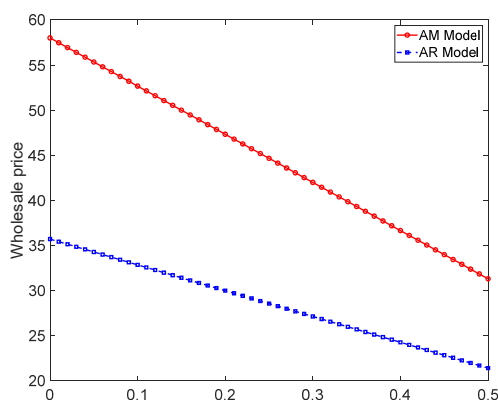


Figure 3. The impact of consumer distrust x on wholesale price.

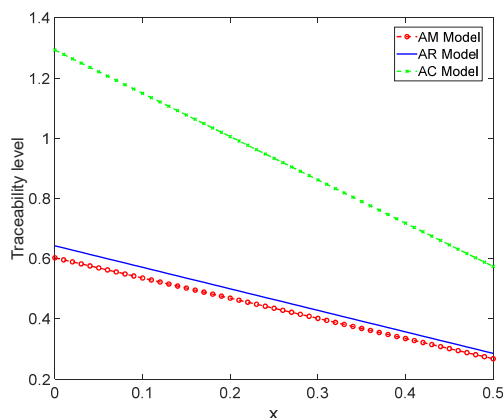


Figure 4. The influence of consumer distrust x on the traceability level.

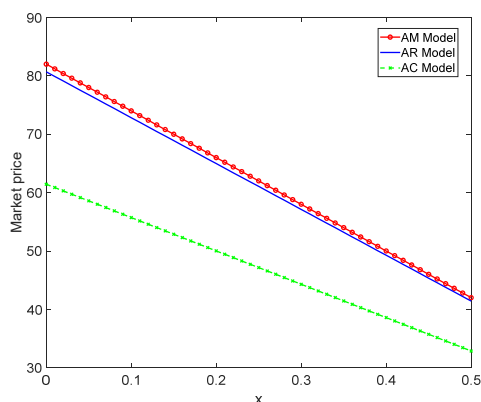


Figure 5. The impact of consumer distrust x on the market price.

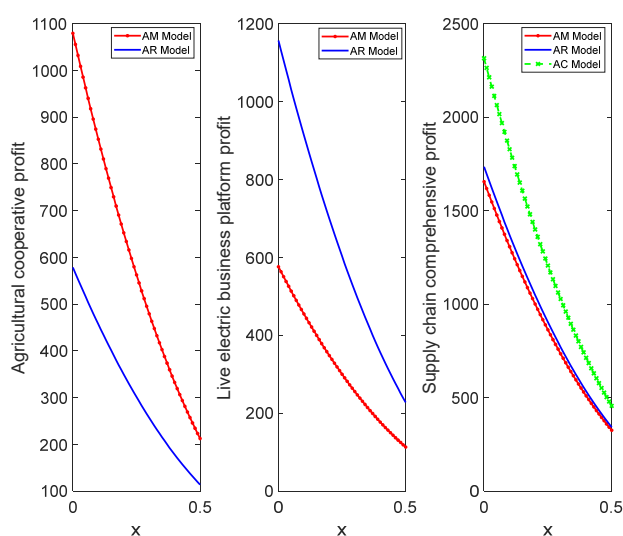


Figure 6. The impact of consumer distrust x on SC profit under different decision-making structures.

5.2. Analysis of SC decisions when introducing blockchain

In this section, when introducing blockchain, we explore the impact of the consumer trust gain coefficient and the utility of traceability effort on the decisions and profits of each member in the agri-product SC under heterogeneous power structures. Refer to Reference [73], and based on the actual situation of this article, the specific parameter settings are as shown in the Table 5:

Table 5. Parameter assignment table after the introduction of blockchain.

Parameter	a	b	c	r	C_b	k_g	k
Value	100	1	10	0.15	50	500	400

The impact of the consumer trust gain coefficient and the utility of traceability effort on the relevant decisions and profits of each member in the SC is as follows:

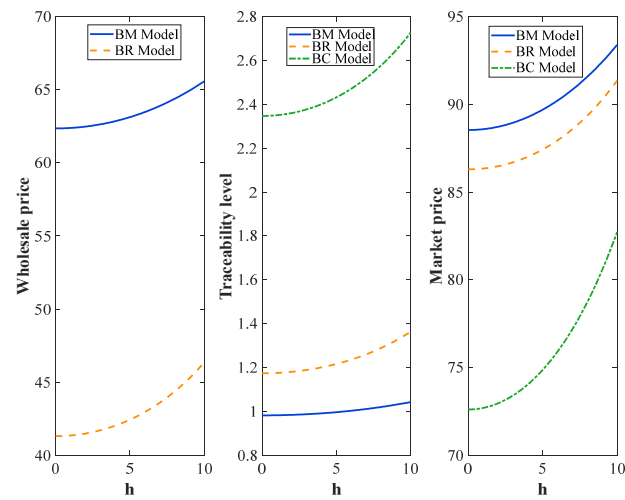


Figure 7. The influence of trust gain coefficient h on the decision variables: wholesale price, traceability level, and market price.

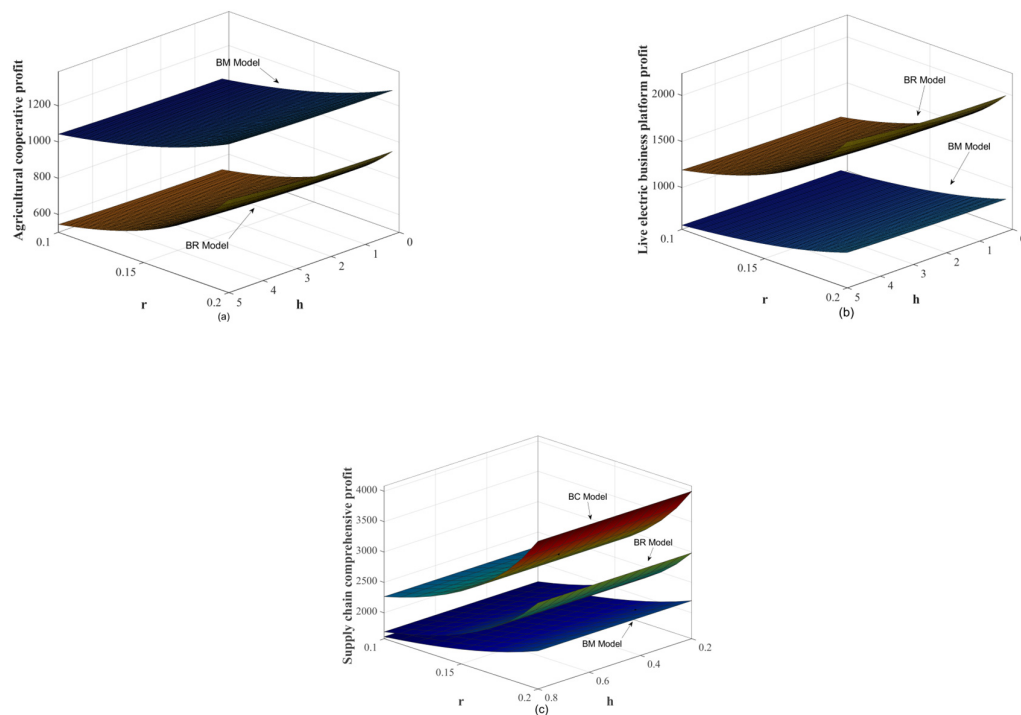


Figure 8. Effects of trust gain coefficient h and traceability utility coefficient r on entity profits under different decision-making structures.

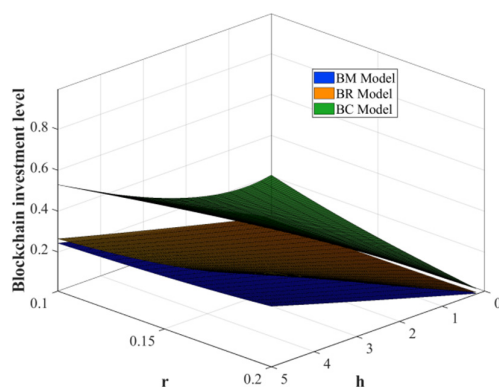


Figure 9. The impact of trust gain coefficient h and the utility of the traceability effort r on the level of blockchain investment.

After the introduction of blockchain technology, as the trust gain coefficient increases, the wholesale prices, market prices, and agricultural traceability levels of the SC all show an upward trend; at the same time, the utility brought by the trust gain coefficient and the traceability level enhances the overall profit of the SC and promotes the increase in the level of blockchain investment. This indicates that blockchain not only improves the transparency of information and consumer trust, but also has a positive impact on the pricing strategy and investment decisions of the SC. When introducing blockchain, the optimal pricing strategy for the agri-product SC satisfies the following relationship:

(1) As shown in Figure 7, the wholesale price satisfies $w_{BM} > w_{AR}$, the wholesale price under the manufacturer's leadership is the highest; the market price satisfies $p_{BM} > p_{BR} > p_{BC}$, the market price under the manufacturer's leadership is the highest; the traceability level of agri-products satisfies $e_{BM} < e_{BR} < e_{BC}$, the agricultural traceability level under the centralized decision-making model is the highest. Moreover, the trust gain coefficient has a positive promoting effect on each decision variable of the SC.

(2) As shown in Figure 8, the profit of the agri-product SC satisfies $\pi_{BM}^c < \pi_{BR}^c < \pi_{BC}^c$, $\pi_{AM}^m > \pi_{AM}^r$, $\pi_{BR}^m < \pi_{BR}^r$.

(3) As shown in Figure 9, the blockchain investment level satisfies $G_{BC} > G_{BR} > G_{BM}$, the blockchain investment level under the centralized decision-making model is the highest.

5.3. The impact of blockchain investment on pricing strategies in heterogeneous power structures

The fourth part separately analyzes the SC decision-making situations of the three heterogeneous power structures in the scenarios without and with the introduction of blockchain and examines the pricing strategies in the equilibrium state. Based on this, this part further considers the decision-making models of the three heterogeneous power structures with the introduction of blockchain and through comparative analysis, explores under what circumstances the introduction of blockchain can better optimize the decisions.

To simplify the subsequent formulas, some parameters will be defined as

$$S = ar + bdl, U = a - bc,$$

$$\Phi = 4b - \frac{h^2}{k_g} - \frac{a^2 r^2}{k},$$

$$\Lambda = C_b + \frac{k(6bk - (ar + bdl)^2)(bc + a(x-1) + bg_0 l)^2}{2(4bk - (ar + bdl)^2)^2},$$

$$O = (3k - dlS)(U - ax) + g_0 l(bk - arS),$$

$$\Delta_N = 4bk - S^2,$$

$$Z = 2C_b + \frac{kV^2}{\Delta_N},$$

$$A = 2C_b + \frac{k(6bk - S^2)V^2}{(4bk - S^2)^2}, B = \sqrt{1 + \frac{8bA}{U^2}},$$

$$V = a(1-x) - bc - bg_0 l.$$

Proof.

Let $w_{AM} - w_{BM} = 0$ and solve for threshold h_1 . When $h < h_1$, $w_{AM} > w_{BM}$; when $h > h_1$, $w_{AM} < w_{BM}$. Similarly, other proofs for this section can be obtained, so they are omitted.

5.3.1. Comparison between AM model and BM model

Theorem 6.

(1) When $h < h_1$, $w_{AM} > w_{BM}$; when $h > h_1$, $w_{AM} < w_{BM}$, and

$$h_1 = \frac{\sqrt{k_g} \sqrt{-\frac{xa^3 r^2 + 2a^2 bdlr + g_0 a^2 blr^2 + ab^2 d^2 l^2 - 2cab^2 dlr - 4kxab - cb^3 d^2 l^2 - 4g_0 kb^2 l}{bc - a + ax + bg_0 l}}}{\sqrt{k}}. \quad (47)$$

(2) When $h < h_2$, $p_{AM} > p_{BM}$; when $h > h_2$, $p_{AM} < p_{BM}$, and

$$h_2 = \sqrt{k_g \left(4b - \frac{a^2 r^2}{k} - \frac{3U(4bk - S^2)}{O} \right)}. \quad (48)$$

(3) When $h < h_3$, $e_{AM} > e_{BM}$; when $h > h_3$, $e_{AM} < e_{BM}$, and

$$h_3 = \sqrt{\frac{k_g [SV(4bk - a^2 r^2) - arU(4bk - S^2)]}{kSV}}. \quad (49)$$

(4) When $h < h_4$, $\pi_{AM}^m > \pi_{BM}^m$; when $h > h_4$, $\pi_{AM}^m < \pi_{BM}^m$, and

$$h_4 = \sqrt{k_g \left(4b - \frac{a^2 r^2}{k} - \frac{U^2}{Z} \right)}. \quad (50)$$

(5) When $h < h_5$, $\pi'_{AM} > \pi'_{BM}$; when $h > h_5$, $\pi'_{AM} < \pi'_{BM}$, and

$$h_5 = \frac{\sqrt{k_g} \sqrt{-\frac{xa^3r^2 + 2a^2bdlr + g_0a^2blr^2 + ab^2d^2l^2 - 2cab^2dlr - 4kxab - cb^3d^2l^2 - 4g_0kb^2l}{bc - a + ax + bg_0l}}}{\sqrt{k}}. \quad (51)$$

(6) When $h < h_6$, $\pi^c_{AM} > \pi^c_{BM}$; when $h > h_6$, $\pi^c_{AM} < \pi^c_{BM}$, and

$$h_6 = \sqrt{k_g \left(4b - \frac{a^2r^2}{k} - \frac{U^2(1+B)}{2A} \right)}. \quad (52)$$

5.3.2. Comparison between AR model and BR model

Theorem 7.

(1) When $h < h_7$, $w_{AR} > w_{BR}$; when $h > h_7$, $w_{AR} < w_{BR}$, and

$$h_7 = \frac{\sqrt{k_g} \sqrt{-\frac{xa^3r^2 + g_0la^2br^2 + dla^2br - cdlab^2r - 2kxab - 2g_0klb^2}{bc - a + ax + bg_0l}}}{\sqrt{k}}. \quad (53)$$

(2) $p_{AR} < p_{BR}$.

(3) When $h < h_8$, $e_{AR} > e_{BR}$; when $h > h_8$, $e_{AR} < e_{BR}$, and

$$h_8 = \frac{\sqrt{k_g} \sqrt{-\frac{a^3r^2 + a^3r^2x - 4abkx - 4b^2g_0kl - a^2bcr^2 + a^2bg_0lr^2 + 2a^2bdlr - 2ab^2cdlr}{bc - a + ax + bg_0l}}}{\sqrt{k}}. \quad (54)$$

(4) When $h < h_9$, $\pi^m_{AR} > \pi^m_{BR}$; when $h > h_9$, $\pi^m_{AR} < \pi^m_{BR}$, and

$$h_9 = \sqrt{k_g \left(2b - \frac{a^2r^2}{k} - \frac{U^2}{O} \right)}. \quad (55)$$

(5) $\pi'_{AR} > \pi'_{BR}$.

(6) When $h < h_{10}$, $\pi^c_{AR} > \pi^c_{BR}$; when $h > h_{10}$, $\pi^c_{AR} < \pi^c_{BR}$, and

$$h_{10} = \sqrt{\frac{\Phi}{C_b k} \left[\frac{k(6bk - S^2)V^2}{8\Delta_N^2} + \frac{8C_b k_g a^2 r^2 + 3k k_g a^2 - 6k k_g abc + 3k k_g b^2 c^2 - 16C_b k k_g b}{8\Phi} \right]}. \quad (56)$$

5.3.3. Comparison between AC model and BC model

Theorem 8.

(1) When $h < h_{11}$, $p_{AC} > p_{BC}$; when $h > h_{11}$, $p_{AC} < p_{BC}$, and

$$h_{11} = \sqrt{k_g} \sqrt{\frac{2bk - a^2r^2}{k} + \frac{(2bk - (ar + bdl)^2)(a - bc)}{(k - dl(ar + bdl))(bc + a(x - 1) + bg_0l) - g_0l(2bk - (ar + bdl)^2)}}. \quad (57)$$

(2) When $h < h_{12}$, $e_{AC} > e_{BC}$; when $h > h_{12}$, $e_{AC} < e_{BC}$, and

$$h_{12} = \frac{\sqrt{k_g} \sqrt{\frac{a^4 r^3 x - 2b^3 d g_0 k l^2 + a^3 b d l r^2 + a^3 b g_0 l r^3 + 2ab^2 d k l - 2b^3 c d k l - 2a^2 b k r x + a^2 b^2 d^2 l^2 r}{-2ab^2 g_0 k l r - 2ab^2 d k l x + a^2 b^2 d g_0 l^2 r^2 + a^3 b d l r^2 x - a^2 b^2 c d l r^2 - ab^3 c d^2 l^2 r}}}{\sqrt{S} \sqrt{k}}. \quad (58)$$

(3) When $h < h_{13}$, $\pi_{AC}^c > \pi_{BC}^c$; when $h > h_{13}$, $\pi_{AC}^c < \pi_{BC}^c$, and

$$h_{13} = \sqrt{k_g} \sqrt{\frac{2bk - a^2 r^2}{k} - \frac{(2bk - (ar + bdl)^2)(a - bc)^2}{2C_b(2bk - (ar + bdl)^2) + k(bc + a(x - 1) + b g_0 l)^2}}. \quad (59)$$

5.3.4. Numerical analysis

Table 6. Parameter assignment table.

Parameter	a	b	c	r	d	l	g_0	k	x	k_g	C_b
Value	100	1	10	0.1	0.1	0.5	0.1	400	0.0001	500	50

Table 7. Summary of threshold values for model comparisons.

Threshold	Decision variable	Model comparison	Value
h_1	Wholesale price	AM vs BM	0.460
h_7	Wholesale price	AR vs BR	0.373
h_3	Traceability level	AM vs BM	3.09
h_8	Traceability level	AR vs BR	0.37
h_{12}	Traceability level	AC vs BC	2.26
h_2	Market price	AM vs BM	0.853
h_{11}	Market price	AC vs BC	0.720
h_4	Manufacturer profit	AM vs BM	9.07
h_9	Manufacturer profit	AR vs BR	8.36
h_5	Retailer profit	AM vs BM	0.460
h_6	SC profit	AM vs BM	6.37
h_{10}	SC profit	AR vs BR	4.94
h_{13}	SC profit	AC vs BC	4.33

Through numerical analysis, the performance of heterogeneous power structures in the SC before and after the introduction of blockchain technology is explored, as well as the impact of the consumer trust gain

coefficient on pricing decisions and profits. Drawing on reference [73] and based on the actual situation of this paper, the parameters are reasonably adjusted. The parameter values are as shown in Table 6:

Theorems 6–8 derive several threshold values of the blockchain trust coefficient h , which determine the transition conditions of wholesale price, traceability level, market price, and profit. To verify whether these thresholds are meaningful under practical parameter settings, numerical verification is conducted before further sensitivity analysis.

All numerical experiments are conducted under the feasible parameter region satisfying the second-order conditions, positive demand constraints, and interior equilibrium requirements. The calculated threshold values are summarized in Table 7.

As shown in Table 6, all threshold values are positive, confirming that the transition points derived in Theorems 6–8 exist within the feasible range of h .

Figures 10–15 further illustrate the threshold transition behavior. Taking wholesale price as an example, Figure 10 shows that the threshold values are $h_1 = 0.460$ and $h_7 = 373$ under manufacturer-led and retailer-led structures, respectively. When h is below the threshold, the blockchain-based model generates a lower equilibrium value than the non-blockchain model. Once h exceeds the threshold, blockchain adoption produces a higher value, indicating that the trust-enhancing effect gradually compensates for the associated investment cost.

Similar threshold transition patterns are observed for traceability level, market price, individual profits, and SC comprehensive profit in Figures 11–15.

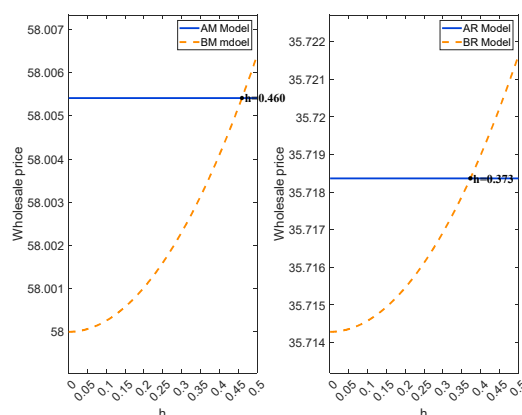


Figure 10. The impact of trust gain coefficient h on wholesale price.

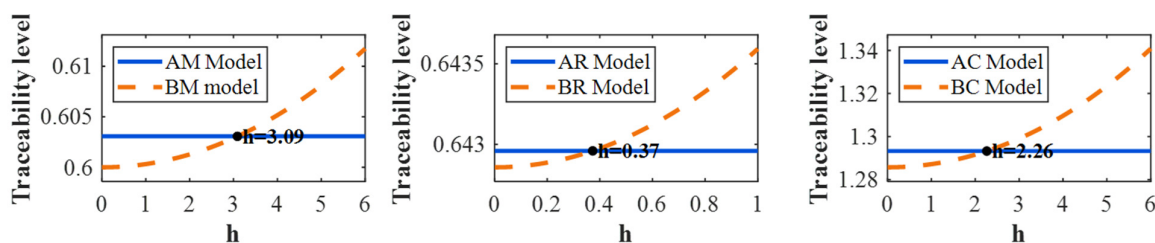


Figure 11. The influence of trust gain coefficient h on the traceability level.

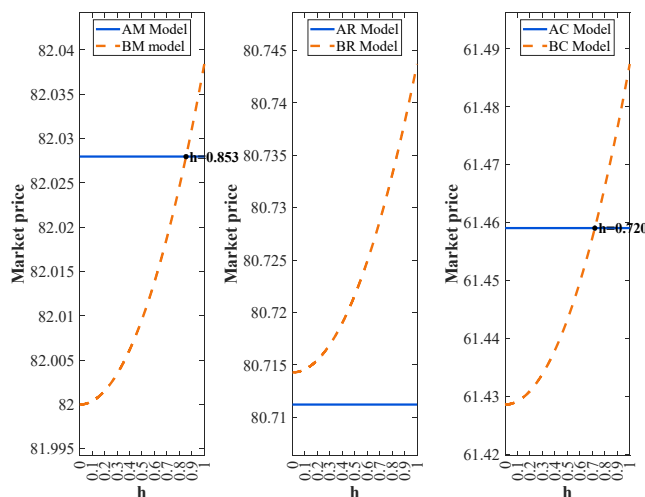


Figure 12. The impact of trust gain coefficient h on market price.

From Figure 10, Figure 11, and Figure 12, it can be seen that regardless of the power structure, after the introduction of blockchain technology, the traceability level of agri-product, wholesale price, and retail price all increase as the consumer trust gain coefficient increases. The application of blockchain technology enhances the traceability level and transparency of agri-products and reduces the information gap for consumers when purchasing agri-products. As consumers' trust in blockchain increases, that is, as the trust gain coefficient increases, they are more willing to pay a premium for agri-products with higher transparency and security. Cooperatives and e-commerce platforms will choose to raise prices to obtain higher profits.

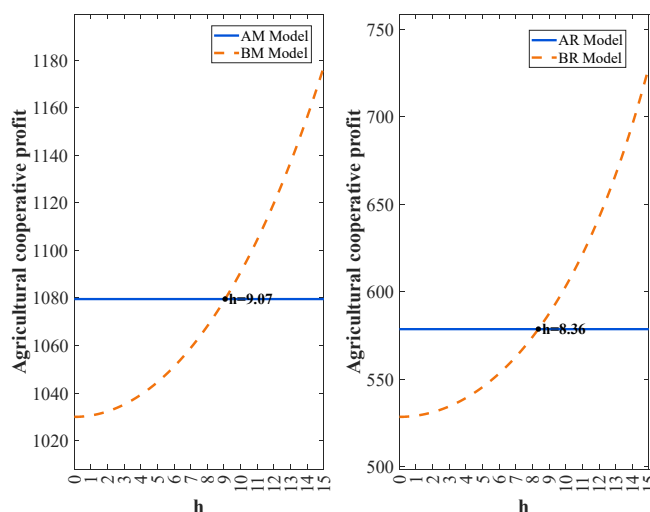


Figure 13. The impact of trust gain coefficient h on the profit of the agricultural cooperative.

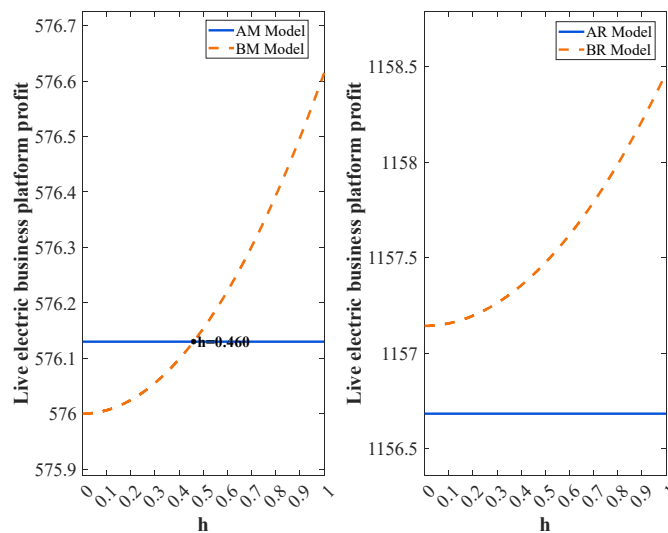


Figure 14. The impact of trust gain coefficient h on the profit of the Live electric business platform profit.

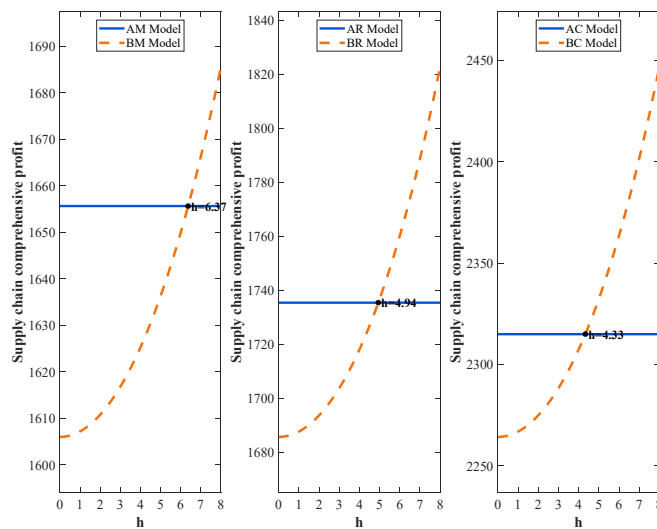


Figure 15. The impact of trust gain coefficient h on the SC comprehensive profit.

From Figure 13, Figure 14, and Figure 15, it can be seen that in any power structure, after the introduction of blockchain technology, as the sensitivity of consumers to traceability increases, the profits of all parties show an upward trend. This phenomenon is attributed to the increase in consumers' attention to traceability information. Consumers are more willing to purchase agri-products with clear traceability, thereby increasing the sales volume of agri-products and further increasing the profit margin.

Since different thresholds correspond to different performance indicators, their numerical values reflect different transition conditions rather than a unified ranking relationship. Therefore, this study focuses on the existence and economic feasibility of each threshold instead of establishing an overall ordering among all thresholds.

5.3.5. Sensitivity analysis

To examine the robustness of the numerical results, a sensitivity analysis is conducted by varying several key parameters, including the price elasticity coefficient b , blockchain input level cost coefficient k_g , and the utility of the traceability effort r . The results show that the positive impact of blockchain-induced trust improvement on SC performance remains unchanged under different parameter settings.

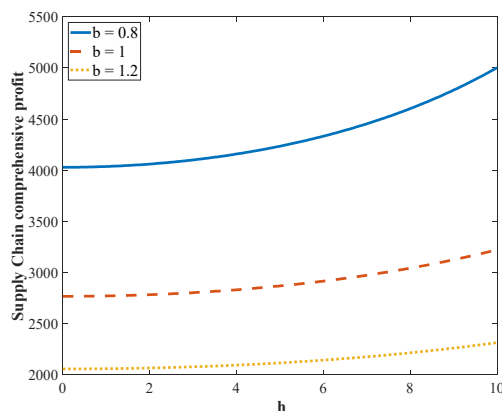


Figure 16. The impact of price elasticity coefficient b on SC profit.

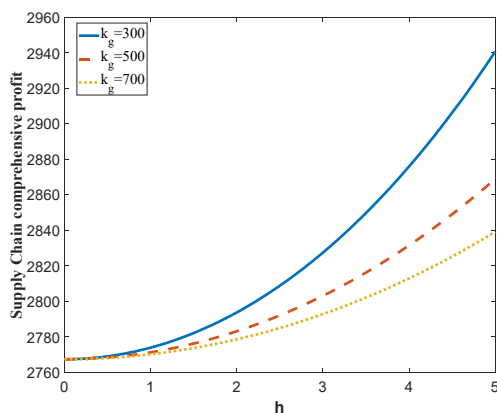


Figure 17. The impact of blockchain input level cost coefficient k_g on SC profit.

Figure 16 investigates the influence of the price elasticity coefficient b on SC profit. The results demonstrate that the SC profit consistently increases with the trust gain coefficient h under different levels of consumer price sensitivity. Although higher price sensitivity reduces the profit level due to intensified demand response to price changes, it does not alter the positive effect of consumer trust enhancement on SC performance.

Figure 17 illustrates the impact of the blockchain input level cost coefficient k_g on SC profit. As shown in the figure, the SC profit increases with the trust gain coefficient h under different values

of k_g . This indicates that the improvement effect of consumer trust generated by blockchain-enabled information transparency remains effective despite variations in blockchain investment costs. Meanwhile, a higher k_g reduces the overall profit level because higher blockchain investment costs weaken the economic benefits obtained from blockchain adoption.

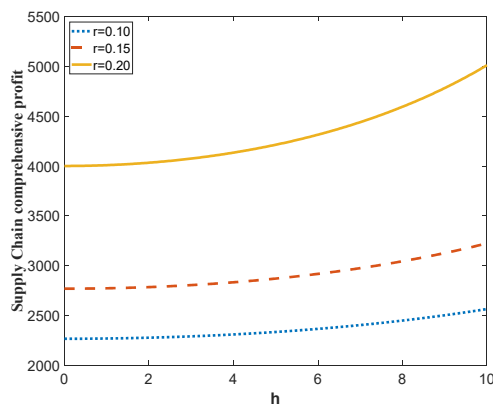


Figure 18. The impact of the utility of the traceability effort r on SC profit.

Figure 18 presents the sensitivity analysis of the utility of the traceability effort r . The results show that the SC profit increases with the trust gain coefficient h under different values of r . A higher r leads to a higher profit level because consumers with stronger sensitivity to traceability information are more responsive to blockchain-enabled information transparency. Therefore, the value generated by consumer trust enhancement becomes more significant when consumers place greater importance on traceability information. Meanwhile, the positive effect of the trust gain coefficient h remains unchanged, indicating that the main conclusion is robust to variations in consumer traceability sensitivity.

Overall, the sensitivity analysis demonstrates that the main conclusions obtained from the benchmark numerical analysis are not driven by a specific parameter setting. Changes in demand elasticity, blockchain investment cost, and traceability sensitivity affect the magnitude of SC profit, but do not alter the positive impact of blockchain investment on SC performance.

5.4. Discussion

By using numerical analysis methods, this paper systematically examines whether the introduction of blockchain and heterogeneous power structures have an impact on the pricing strategies and profit levels of the agri-product SC. At the same time, it further conducts a comparative analysis of the pricing decisions and profit changes of the SC members before and after the application of blockchain technology from a longitudinal perspective. Based on this, the main conclusions of this part are as follows:

(1) Before the introduction of blockchain, our model shows that consumer distrust exerts a negative regulatory effect on various decision variables through the amplification mechanism of information asymmetry. An increase in consumer distrust implies that consumers hold a stronger skeptical attitude towards the source information of agri-products. Given the same price and

traceability level, the actual demand volume decreases. To alleviate the pressure of declining sales, retailers choose to lower retail prices. This price signal travels up the SC, causing wholesale prices to fall synchronously. In terms of the traceability investment level, the shrinking demand reduces the expected return on unit traceability investment, and cooperatives, balancing the cost and benefit, reduce the level of traceability. The reduction in traceability investment further weakens the attractiveness of the product to consumers, forming a negative feedback loop in which demand and investment interact downward. Eventually, the narrowing of the price space and the weakening of investment incentives jointly erode the marginal profits of each link in the SC. The profits of manufacturers, retailers, and the system as a whole all decrease as consumer distrust increases, demonstrating the systematic drag of the distrust factor on the overall performance of the SC.

(2) After the introduction of blockchain technology, our model shows that consumers' distrust of the origin of agri-products can be mitigated and the losses caused by negative evaluations can be reduced. Moreover, as the trust gain coefficient of consumers increases, the wholesale price, market price, traceability level, blockchain investment level, and SC profit of agri-products all exhibit an increasing trend. However, it is worth noting that due to the existence of fixed application costs of blockchain, when introducing blockchain technology, not only should the operating costs be considered but the fixed costs should be taken into account also.

(3) After the introduction of blockchain technology, our model shows that the trust gain coefficient exhibits a significant threshold effect: when this coefficient exceeds the critical value, the advantages of blockchain technology in terms of traceability, pricing decisions, and profits for all parties can be better realized, and the overall performance is improved compared with the scenario without blockchain. This pattern holds true under all three power structures, indicating that the performance-enhancing effect of blockchain is closely related to the accumulation of consumer trust in it.

(4) Regardless of whether blockchain technology is introduced or not, our model shows that the SC performance under the centralized decision-making model is better than that of the two decentralized decision-making models. The centralized decision-making aims to maximize the overall profit of the system, which helps to eliminate the double marginalization and investment incentive distortions in decentralized games, thereby achieving a higher traceability level, lower retail prices, and better total SC profits. After introducing blockchain technology, the reduction of consumer distrust and the release of the trust gain effect further strengthened these advantages. The centralized decision-making exhibits improvements in dimensions such as blockchain investment level, market demand, and system profits compared to the situation without its introduction. These results suggest that from the perspective of SC coordination efficiency and technological empowerment effect, the collaborative application of centralized decision-making and blockchain technology can be an effective approach to achieve the optimal overall performance of the agri-product SC.

6. Conclusion

This paper establishes a two-level SC system consisting of cooperatives (manufacturers) and e-commerce platforms (retailers), considering three different SC decisions under heterogeneous power structures. Parameters, such as the degree of consumers' distrust in product origin, the level of blockchain investment, and the level of product traceability, are introduced. The study examines the changes in pricing strategies under three heterogeneous power structures before and after the introduction of blockchain technology. The main research conclusions of this paper are as follows:

6.1. Research conclusion

(1) In the scenario without the introduction of blockchain technology, our model shows that SC decisions and performance exhibit differences depending on the power structure. Regarding the wholesale price, the pricing level is higher when the manufacturer is in control than when the retailer is in control. This result is driven by the fact that the manufacturer can occupy a more favorable bargaining position by virtue of its priority decision-making position. In terms of traceability investment, the centralized decision-making leads to the highest level of traceability among the three structures, followed by the retailer's control, and the lowest when the manufacturer is in control, and the lowest when the manufacturer is in control, reflecting the inhibitory effect of decentralized decision-making on investment incentives. The retail price shows an opposite ranking. The price is highest when the manufacturer is in control, and it is lowest under centralized decision-making, indicating that the decentralization of power is associated with the degree of terminal markup. The total SC profit reaches the highest level under centralized decision-making, followed by the retailer's control, and the lowest when the manufacturer is in control, suggesting an improvement effect of power concentration on overall efficiency. suggesting an improvement effect of power concentration on overall efficiency. In terms of member profit distribution, regardless of the decentralized structure, the profit of the leading party is higher than that of the follower, which is consistent with the basic logic of the first-mover advantage.

The increase in consumer distrust level has a consistent negative impact on these decision variables. The intensification of distrust is associated with weakened purchase intention, leading to a contraction in market demand, retailers tending to lower retail prices to maintain sales volume, and wholesale prices also declining accordingly. The shrinking demand simultaneously reduces the expected return on unit traceability investment, and cooperatives, weighing cost against benefit, reduce the level of traceability. These adjustments further squeeze the marginal profit space. The manufacturer, retailer, and total SC profit all decrease with the increase in distrust level, suggesting that the deterioration of information asymmetry ultimately affects the economic sustainability of the SC through paths, such as suppressing demand, distorting pricing, and weakening investment incentives.

(2) In the scenario with the introduction of blockchain technology, our model shows that SC decisions and performance exhibit similar regular characteristics to those without the introduction of the technology, and the mitigating effect of blockchain on consumers' distrust further strengthens the overall performance of the system. Regarding the wholesale price, the pricing level is still higher when the manufacturer is in control than when the retailer is in control, indicating that even with the reduction of information asymmetry, the distribution effect of power structure on the upstream pricing power remains significant. The levels of traceability and blockchain investment both show the highest level under centralized decision-making, followed by the retailer's control, and the lowest when the manufacturer is in control, reflecting the positive effect of power concentration on technological investment incentives. The retail price is highest when the manufacturer is in control and lowest under centralized decision-making, consistent with the scenario without the introduction of blockchain. This suggests that the double marginalization effect has not been eliminated by the introduction of blockchain. The total SC profit reaches the optimal level under centralized decision-making, and the retailer's control is slightly better than the manufacturer's control in decentralized decision-making, further supporting the improvement effect of power concentration on overall efficiency. In terms of member profit distribution, the profit of the leading party is always higher than that of the follower

and the first-mover advantage still exists. It is worth noting that the introduction of blockchain technology can mitigate consumers' distrust in the origin of agri-products, and the demand suppression effect caused by information asymmetry can be partially alleviated. This change can increase the overall scale of market demand, providing more pricing space and investment incentives for SC members. Under centralized decision-making, the level of blockchain investment is the highest, the synergy effect of traceability information and trust gain can be better utilized, and the system profit is improved compared with the scenario without blockchain. Even in a decentralized decision-making system, the demand expansion brought about by trust restoration partially alleviated the double marginalization distortion and the profits of each member improve to varying degrees. These results suggest that blockchain technology effectively enhances the overall coordination efficiency and value creation capability of the agri-product SC by mitigating information asymmetry and enhancing consumer trust.

(3) The introduction of blockchain technology systematically improves the decision-making efficiency and profit levels of the agri-product SC under heterogeneous power structures by mitigating consumer distrust. The centralized decision-making, with its goal of maximizing overall system profits, outperforms the manufacturer-led and retailer-led decentralized models in terms of blockchain investment level, traceability intensity, and total profits, more fully releasing the demand expansion effect of trust restoration. The power structure has a moderating effect on the distribution of blockchain benefits: The retailer-led model, due to its closer proximity to the consumer end, exhibits better blockchain investment incentives and performance than the manufacturer-led model, but the inherent double marginalization distortion in decentralized decision-making has not been fully addressed. Although the problems of high retail prices and insufficient investment incentives still exist, blockchain empowerment has improved the profits of members under each power structure and the total system profits compared to before the introduction, contributing to the coordinated evolution of the overall coordination efficiency and value creation capability of the SC.

6.2. Management insights

(1) Optimize the power allocation and collaboration mechanism of the SC.

Our model shows that centralized decision-making achieves higher traceability investment levels, better price coordination, and greater overall profit compared with decentralized decision-making, indicating that SC coordination is essential for improving operational efficiency. Therefore, when SC members have sufficient cooperation willingness and integration capability, they may enhance collaboration through strategic alliances, joint production and sales planning, information sharing, and benefit-sharing contracts to reduce the efficiency loss caused by double marginalization. For decentralized SC where centralized operation is difficult to achieve, coordination mechanisms should be designed according to different power structures. Specifically, the dominant member should take greater responsibility for coordinating resources and promoting cooperation, while revenue-sharing, cost-sharing, and incentive mechanisms can be adopted to encourage participation from other members, thereby improving decision-making efficiency and achieving a better allocation of SC benefits under existing power constraints.

(2) Incorporate consumer trust governance into the core management objectives of the SC.

Our model shows that consumer distrust reduces market demand, weakens the incentive for traceability investment, and decreases SC profitability, indicating that consumer trust is not only a

market outcome but also a critical management variable. Therefore, when products involve high information asymmetry, or consumers have limited ability to verify product quality, SC enterprises should prioritize trust governance by improving traceability systems, strengthening quality certification, and enhancing information disclosure. In addition, enterprises should focus on increasing the effectiveness of trust enhancement mechanisms, because a higher consumer trust gain coefficient can better transform information transparency into demand improvement and economic benefits. These measures can reduce the negative impact of consumer distrust and improve the long-term sustainability of the SC.

(3) Make blockchain adoption decisions based on economic conditions and power structures.

Our model shows that blockchain can reduce information asymmetry, alleviate consumer distrust, and improve SC performance by enhancing information transparency. However, blockchain adoption is not always beneficial, and its value depends on the balance between trust enhancement benefits and investment costs. Therefore, enterprises should adopt blockchain when the improvement in consumer trust and demand generated by blockchain can compensate for the related investment costs, particularly when consumers show strong sensitivity to traceability information or the trust gain effect is significant. In addition, blockchain investment and benefit-sharing mechanisms should be designed according to different power structures. In a manufacturer-dominated SC, the manufacturer should undertake a larger share of investment responsibility due to its stronger control over production and information processes; in a retailer-dominated SC, the retailer should participate more actively because it directly benefits from improved consumer trust and market demand; under centralized decision-making, investment costs should be allocated according to the overall SC benefits to achieve better coordination.

6.3. Theoretical contributions

This study contributes to the existing literature in three aspects. First, this study extends the research on blockchain-enabled traceability in agricultural SC. Previous studies mainly focus on the construction of blockchain-based traceability systems and emphasize their effects on improving information transparency, food safety, and product credibility [25]. Recent studies further examine the impact of blockchain adoption on food SC performance, but mainly from the perspective of operational improvement rather than the strategic interactions among SC members [42]. Different from these studies, this paper incorporates blockchain investment into an SC game framework and investigates how blockchain technology affects traceability decisions, pricing strategies, and profit distribution under different power structures.

Second, this study enriches the literature on SC traceability and power structures. Existing studies have explored the effects of consumer preferences, government subsidies, and different leadership structures on traceability investment decisions in agricultural SC [57]. However, the role of blockchain as a digital technology that changes information transparency and coordination mechanisms remains insufficiently explored. By considering manufacturer-led, retailer-led, and centralized decision-making scenarios, this study reveals how blockchain-enabled information transparency influences SC decisions and performance under heterogeneous power structures.

Third, this study extends the literature on blockchain and consumer trust. Existing studies mainly investigate how blockchain-driven traceability and transparency enhance consumer trust and purchase behavior [32,44]. However, limited attention has been paid to how consumer distrust affects firms'

operational decisions and economic outcomes. By introducing consumer distrust and trust gain mechanisms into the SC model, this study reveals the interaction mechanism among consumer trust, blockchain adoption, traceability investment, and SC performance.

6.4. Limitations and future research directions

This paper treats the trust-improving effect of the underlying blockchain foundation as the institutional effect resulting from the transformation of the governance model. It does not further establish a continuous function of consumer trust gradually recovering with the increase of blockchain investment. Therefore, the focus of the model lies in comparing the differences in equilibrium decisions and operating performance of enterprises under the non-blockchain mode and the blockchain mode, rather than identifying the dynamic trust restoration path of blockchain investment.

In addition, this study adopts a benchmark demand function in which blockchain investment and traceability effort affect consumer demand through separate mechanisms. Future research can further consider nonlinear trust-restoration functions, the complementary effects between blockchain investment and traceability effort, as well as practical factors (e.g., implementation uncertainty and interoperability constraints), to provide a more comprehensive analysis of blockchain adoption decisions.

Author contributions

Yueyang Gan: Conceptualization, Methodology, Writing–review and editing, Visualization, Writing–original draft; Xianrong Hu: Conceptualization, Methodology, Investigation, Formal analysis, Software, Validation; Tonghua Yang: Investigation, Data curation, Validation, Writing–review and editing. Xiaoqing Huang: Supervision, Validation, Project administration, funding acquisition, Writing–review and editing; Fangbing Liu: Validation and funding acquisition; Junke Qiu: Validation and funding acquisition; All authors have read and approved the final version of the manuscript.

Use of Generative-AI tools declaration

The authors declare they have not used Artificial Intelligence tools in the creation of this article.

Acknowledgements

This research was funded by Jiangxi Humanities and Social Science Research Project (GL24108), (GL24209) and (GL24223), Prosperous Philosophy and Social Science Research Project of Jiangxi University of Science and Technology (FZ25-ZX-29) and (FZ25-ZX-04) and Jiangxi University of Science and Technology (JXUST-SKRC-14).

Conflict of interest

The authors declare no conflicts of interest.

References

1. H. Kendall, S. Kuznesof, M. Dean, M. Chan, B. Clark, R. Home, et al., Chinese consumer's attitudes, perceptions and behavioural responses towards food fraud, *Food Control*, **95** (2019), 339–351. <https://doi.org/10.1016/j.foodcont.2018.08.006>
2. R. Liu, Z. Gao, R. M. Nayga, H. A. Snell, H. Ma, Consumers' valuation for food traceability in China: Does trust matter, *Food Policy*, **88** (2019), 101768. <https://doi.org/10.1016/j.foodpol.2019.101768>
3. S. Li, Y. Wang, G. M. L. Tacken, Y. Liu, S. J. Sijtsema, Consumer trust in the dairy value chain in China: The role of trustworthiness, the melamine scandal, and the media, *J. Dairy Sci.*, **104** (2021), 8554–8567. <https://doi.org/10.3168/jds.2020-19733>
4. S. Maitiniyazi, M. Canavari, Exploring Chinese consumers' attitudes toward traceable dairy products: A focus group study, *J. Dairy Sci.*, **103** (2020), 11257–11267. <https://doi.org/10.3168/jds.2020-18408>
5. L. Ding, M. Liu, Y. Yang, W. Ma, Understanding Chinese consumers' purchase intention towards traceable seafood using an extended Theory of Planned Behavior model, *Mar. Policy*, **137** (2022), 104973. <https://doi.org/10.1016/j.marpol.2022.104973>
6. X. Wang, J. Zhang, J. Chen, Y. Qiu, C. Zhao, The impact of digital traceability technology on green agricultural product purchase intention, *Front. Sustain. Food Syst.*, **10** (2026), 1747859. <https://doi.org/10.3389/fsufs.2026.1747859>
7. J. Bai, Melons as lemons: asymmetric information, consumer learning and seller reputation, *Rev. Econ. Stud.*, **92** (2025), 3574–3610. <https://doi.org/10.1093/restud/rdaf006>
8. M. Vasileiou, L. S. Kyrgiakos, C. Kleisiari, P. Z. Lappas, C. Tsinopoulos, G. Kleftodimos, et al., Digital transformation of food supply chain management using blockchain: A systematic literature review towards food safety and traceability, *Bus. Inf. Syst. Eng.*, **68** (2026), 919–946. <https://doi.org/10.1007/s12599-025-00948-0>
9. H. Schirmacher, O. Elshiewy, Y. Boztug, That's not natural! Consumer response to disconfirmed expectations about natural food, *Appetite*, **180** (2023), 106270. <https://doi.org/10.1016/j.appet.2022.106270>
10. Z. Liu, X. Li, C. Wu, R. Zhang, D. K. Durrani, The impact of expectation discrepancy on food consumers' quality perception and purchase intentions: Exploring mediating and moderating influences in China, *Food Control*, **133** (2022), 108668. <https://doi.org/10.1016/j.foodcont.2021.108668>
11. V. Arnold, T. Guggenberger, J. Stramm, N. Urbach, Designing a blockchain-based information system for procurement processes—Balancing decentralization, scalability, and security while maintaining privacy, *Inf. Syst.*, **140** (2026), 102723. <https://doi.org/10.1016/j.is.2026.102723>
12. Y. Mei, N. Deng, From technological signal to behavioral response: Unraveling the influence of blockchain traceability labels in fresh e-commerce, *J. Retail. Consum. Serv.*, **92** (2026), 104826. <https://doi.org/10.1016/j.jretconser.2026.104826>
13. C. D. Duong, Blockchain technology and organic food consumption: A polynomial regression-based approach to explore the role of trust in retailers and producers, *Technol. Forecast. Soc. Change.*, **228** (2026), 124672. <https://doi.org/10.1016/j.techfore.2026.124672>
14. Y. Chen, J. Luo, Blockchain-enabled traceability and visibility: Financing for a capital-constrained recycler in closed-loop supply chain, *Transp. Res. Part E*, **211** (2026), 104826. <https://doi.org/10.1016/j.tre.2026.104826>

15. R. Bakhat, J. García-Mestanza, Motivational barriers to blockchain adoption in hospitality and tourism: an extended expectancy-trust framework in the Spanish context, *J. Hosp. Tour. Insights.*, **9** (2026), 155–175.
16. P. K. Manoharan, S. K. Tiwari, V. Sharma, Circular economy and waste management: A literature review in perishable supply chain management, *Socio-Econ. Plan. Sci.*, **105** (2026), 102455. <https://doi.org/10.1016/j.seps.2026.102455>
17. R. Shi, Y. Chen, F. Yang, X. Wang, A novel profit distribution algorithm of agricultural products E-commerce supply chain considering the influence of empathy and power structure, *Int. J. Syst. Assur. Eng. Manag.*, (2026), 1–13. <https://doi.org/10.1007/s13198-026-03298-6>
18. C. Zhu, J. Ma, J. Li, M. Goh, Retailer alliance and power structure shift in green brand supply chain under low-carbon operating environment, *Int. J. Prod. Res.*, **64** (2026), 2753–2779. <https://doi.org/10.1080/00207543.2025.2583474>
19. M. Yu, E. Cao, Y. Zhang, ESG investment under different supply chain power structures: decisions, impacts, and the triple win, *Expert Syst. Appl.*, **312** (2026), 131518. <https://doi.org/10.1016/j.eswa.2026.131518>
20. M. Yuan, R. Qiu, M. Sun, S. Shao, Z. Fan, H. Xu, Blockchain implementation decisions in a dual-channel supply chain under different market power structures, *Int. J. Prod. Res.*, **63** (2025), 5238–5262. <https://doi.org/10.1080/00207543.2025.2476712>
21. W. Xue, X. Zhou, Z. Xu, Traceability Decisions and coordination contracts in agricultural supply chains under different power structures, *Sustainability*, **17** (2025), 9460. <https://doi.org/10.3390/su17219460>
22. Z. Li, J. He, Q. Xue, Modeling blockchain investment in data-intensive supply chains: A game-theoretic analysis of power structures, *Systems*, **13** (2025), 1029. <https://doi.org/10.3390/systems13111029>
23. L. Xia, L. Wang, R. Xiao, J. Wang, P. Hou, Blockchain and pricing strategies in supply chains considering consumer traceability preference and power structure, *Int. J. Prod. Res.*, **63** (2025), 10147–10166. <https://doi.org/10.1080/00207543.2025.2545433>
24. Q. Zhang, Analysis of agricultural products supply chain traceability system based on internet of things and blockchain, *Math. Probl. Eng.*, **2022** (2022), 3162871. <https://doi.org/10.1155/2022/3162871>
25. G. Lv, C. Song, P. Xu, Z. Qi, H. Song, Y. Liu, Blockchain-based traceability for agricultural products: a systematic literature review, *Agriculture*, **13** (2023), 1757. <https://doi.org/10.3390/agriculture13091757>
26. X. Lin, Analysis of agricultural product information traceability and customer preference based on blockchain, *Wirel. Commun. Mob. Comput.*, **2022** (2022), 1935233. <https://doi.org/10.1155/2022/1935233>
27. G. Zhou, Research review of agricultural product traceability system based on blockchain technology. *Asian J. Econ. Bus. Account.*, **22** (2022), 1–14. <https://doi.org/10.9734/ajeba/2022/v22i1930654>
28. X. Li, J. Du, W. Li, F. Shahzad, Green ambitions: A comprehensive model for enhanced traceability in agricultural product supply chain to ensure quality and safety, *J. Clean. Prod.*, **420** (2023), 138397. <https://doi.org/10.1016/j.jclepro.2023.138397>
29. Y. Tan, X. Huang, W. Li, Does blockchain-based traceability system guarantee information authenticity? An evolutionary game approach, *Int. J. Prod. Econ.*, **264** (2023), 108974. <https://doi.org/10.1016/j.ijpe.2023.108974>

30. Q. Yao, H. Zhang, Improving agricultural product traceability using blockchain, *Sensors*, **22** (2022), 3388. <https://doi.org/10.3390/s22093388>
31. D. Prashar, N. Jha, S. Jha, Y. Lee, G. P. Joshi, Blockchain-based traceability and visibility for agricultural products: A decentralized way of ensuring food safety in India, *Sustainability*, **12** (2020), 3497. <https://doi.org/10.3390/su12093497>
32. V. L. Ta, C. D. Duong, Investigating the role of blockchain-enabled drivers on consumers' organic food consumption: a stimulus-organism-response perspective, *Environ. Res. Commun.*, **7** (2025), 035003. <https://doi.org/10.1088/2515-7620/adb9be>
33. F. Modica, F. Sgroi, G. Giamporcaro, C. Sciortino, Blockchain and food trust: Will consumers pay more, *Sustain. Dev.*, (2026). <https://doi.org/10.1002/sd.70925>
34. C. Gao, C. Xiang, Research on the mechanisms of the impact of agricultural product traceability information characteristics on consumer purchase intentions, *J. Huazhong Agric. Univ.*, **1** (2025), 121–133. <https://doi.org/10.13300/j.cnki.hnwxkb.2025.01.011>
35. Y. Wang, Z. Zhu, Impacts of eWOM and observational learning on consumers' online purchase intention for geographical indication products: The moderating role of trust, *Jiangsu Agric. Sci.*, **49** (2021), 223–230. <https://doi.org/10.15889/j.issn.1002-1302.2021.10.041>
36. X. Du, Y. Wu, H. Gao, M. Li, Effect of negative online review and corporate response on customer purchase intention, *J. Syst. Manag.*, (2021), 926–936.
37. R. E. Halim, S. Rahmani, G. Gayatri, A. Furinto, Y. Sutarso, The effectiveness of product sustainability claims to mitigate negative electronic word of mouth (N-eWOM), *Sustainability*, **14** (2022), 2554. <https://doi.org/10.3390/su14052554>
38. Z. Ni, X. Hou, F. Qian, Does negative reputation inhibit corporate finance? A test based on life cycle theory, *J. Bus. Econ.*, **4** (2022), 54–66. <https://doi.org/10.14134/j.cnki.cn33-1336/f.2022.04.005>
39. Y. Hu, H. Lin, Effects of online-review characteristics on agricultural products sales of fresh e-commerce: Evidence from the big data about mutton products on Taobao platform, *J. China Agric. Univ.*, **26** (2021), 206–218. <https://doi.org/10.11841/j.issn.1007-4333.2021.06.21>
40. P. Qing, H. Huang, A. Razzaq, Y. Tang, M. Tu, Impacts of sellers' responses to online negative consumer reviews: Evidence from an agricultural product, *Can. J. Agric. Econ.*, **66** (2018), 587–597. <https://doi.org/10.1111/cjag.12184>
41. L. Yao, Y. Feng, The impact of negative online reviews of fresh aquatic products on consumers' purchase intentions: Take Jingdong fresh as an example, *Chin. Fish. Econ.*, **41** (2023), 73–81.
42. N. Vu, A. Ghadge, M. Bourlakis, The impact of Blockchain adoption on supply chain performance: evidence from food industry, *Int. J. Prod. Res.*, **63** (2025), 5402–5427. <https://doi.org/10.1080/00207543.2024.2414375>
43. F. Tao, Y. Wang, S. Zhu, Impact of blockchain technology on the optimal pricing and quality decisions of platform supply chains, *Int. J. Prod. Res.*, **61** (2023), 3670–3684. <https://doi.org/10.1080/00207543.2022.2050828>
44. D. Ma, P. Ma, J. Hu, The impact of blockchain technology adoption on an e-commerce closed-loop supply chain considering consumer trust, *Sustainability*, **16** (2024), 1535. <https://doi.org/10.3390/su16041535>
45. H. Yang, W. Yu, Exploring the impacts of employee-based blockchain adoption on supply chain finance and operational performance, *Int. J. Prod. Res.*, **64** (2026), 2491–2509. <https://doi.org/10.1080/00207543.2025.2580535>

46. F. G. Yazıcılar Sola, D. Güzel, The role of supply chain transparency and supplier trust in the impact of blockchain technology adoption on new product development, *Sustainability*, **17** (2025), 5171. <https://doi.org/10.3390/su17115171>
47. Y. S. Cho, E. Jung, P. C. Hong, The impact of blockchain technology on lean supply chain management: cross-validation through big data analytics and empirical studies of U.S. companies, *Systems*, **14** (2026), 3. <https://doi.org/10.3390/systems14010003>
48. S. Yousefi, B. M. Tosarkani, An analytical approach for evaluating the impact of blockchain technology on sustainable supply chain performance, *Int. J. Prod. Econ.*, **246** (2022), 108429. <https://doi.org/10.1016/j.ijpe.2022.108429>
49. C. Xu, G. Bi, C. Wu, The impact of retailer's demand forecast information sharing on platform supply chain efficiency under blockchain technology, *Comput. Ind. Eng.*, **212** (2026), 111688. <https://doi.org/10.1016/j.cie.2025.111688>
50. X. Dong, X. Hao, C. Cai, X. Li, K. Wang, J. Zhang, The impact of blockchain adoption in supply chain systems on corporate performance: a technology–organization–environment framework, *Prod. Plan. Control.*, **36** (2025), 1431–1452. <https://doi.org/10.1080/09537287.2024.2364814>
51. M. Javadi, Z. Raeesi, A. Bohlool, The impact of blockchain technology on supply chain production strategies, *J. Bus. Manag. Stud.*, **7** (2025), 103–118. <https://doi.org/10.32996/jbms.2025.7.4.5>
52. C. D. Duong, T. T. Dao, T. N. Vu, T. V. N. Ngo, M. H. Nguyen, Blockchain-enabled food traceability system and consumers' organic food consumption: A moderated mediation model of blockchain knowledge and trust in the organic food chain, *Sustain. Futures*, **8** (2024). 100316. <https://doi.org/10.1016/j.sftr.2024.100316>
53. F. Zhang, Q. Ji, X. Hu, X. Wang, Pricing model of agricultural supply chains under fairness concerns and blockchain subsidies, *Chin. J. Manag.*, (2025), 1162–1170. <https://doi.org/10.3969/j.issn.1672-884x.2025.06.018>
54. C. Wang, C. Wang, X. Chen, W. Jin, Confirmed warehouse financing under blockchain-driven buy-back guarantee across supply chain tiers, *J. Manag. Sci. China*, (2024).
55. S. Pang, S. W. Teng, M. Murshed, C. V. Bui, P. Karmakar, Y. Li, et al., A survey on evaluation of blockchain-based agricultural traceability, *Comput. Electron. Agric.*, **227** (2024), 109548. <https://doi.org/10.1016/j.compag.2024.109548>
56. X. Niu, Z. Dong, J. Wu, L. Ding, Q. Zhang, Pricing and coordination strategies for agricultural supply chains empowered by blockchain, *Math. Pract. Theory*, **56** (2026), 145–157. <https://doi.org/10.20266/j.math.25-0777>
57. W. Xue, Z. Xu, The impacts of government subsidies and consumer preferences on food supply chain traceability under different power structures, *Sustainability*, **15** (2023), 470. <https://doi.org/10.3390/su15010470>
58. K. Cao, Y. Gao, Optimal fresh agricultural products private brand introduction and sourcing strategy considering different power structures, *Manag. Decis. Econ.*, **44** (2023), 3827–3845. <https://doi.org/10.1002/mde.3922>
59. A. Gao, B. Liu, S. Yue, The impact of channel power structures on integrated mode of recycling in a closed-loop battery supply chain, *Comput. Ind. Eng.*, **208** (2025), 111378. <https://doi.org/10.1016/j.cie.2025.111378>
60. N. Wan, J. Fan, W. Chen, Platform coupon promotion and its effect on an O2O retail supply chain under different power structures, *Electron. Commer. Res.*, (2025), 1–26. <https://doi.org/10.1007/s10660-025-10045-9>

61. Y. Liu, M. G. Tamimu, J. Chai, Dynamic supply chain decision-making of live e-commerce considering Netflix marketing under different power structures, *J. Theor. Appl. Electron. Commer. Res.*, **20** (2025), 202. <https://doi.org/10.3390/jtaer20030202>
62. J. Fan, N. Wan, G. Zhang, The research of investment decisions on quality and traceability in supply chains under different power structures, *J. Syst. Sci. Math. Sci.*, **44** (2024), 2680–2706. <https://doi.org/10.12341/jssms23427>
63. H. Ren, Z. Luo, Decisions and coordination of e-commerce supply chain considering product quality and marketing efforts under different power structures, *Sustainability*, **16** (2024), 5536. <https://doi.org/10.3390/su16135536>
64. Z. Zhang, Z. Chen, M. Wan, S. Qiu, Choice of product quality in supply chain of live-streaming e-commerce under different power structures, *Aust. J. Manag.*, **50** (2025), 266–286. <https://doi.org/10.1177/03128962231196322>
65. X. Liu, Z. Zhou, F. Zhong, Interaction between channel selection and supply chain transparency under varying power structures, *Chin. J. Manag. Sci.*, **34** (2026), 326–336. <https://doi.org/10.16381/j.cnki.issn1003-207x.2023.1490>
66. S. Zhao, X. Cao, W. Li, Research on pricing and coordination of fresh agricultural product supply chain considering the smart agriculture technology under different power structures, *Chin. J. Manag. Sci.*, **33** (2025), 262–278. <https://doi.org/10.16381/j.cnki.issn1003-207x.2024.1149>
67. B. Xu, F. Xie, Y. Zhang, Research on CSR decision and dual coordination contract under different power structures in fresh produce supply chain, *J. Syst. Sci. Math. Sci.*, (2025). <https://doi.org/10.12341/jssms250353>
68. C. Zhang, Y. Zhu, Y. Yuan, Smart supply chain decision under platform digital empowerment and technology investment, *Comput. Integr. Manuf. Syst.*, **31** (2025), 1059–1069. <https://doi.org/10.13196/j.cims.2022.0776>
69. K. Zhang, M. Ma, Research on dual-channel supply chain coordination considering fresh e-tailer's returns, *J. Donghua Univ. (Nat. Sci. Ed.)*, **47** (2021), 116–123. <https://doi.org/10.19886/j.cnki.dhdz.2020.0325>
70. X. Xing, R. Miao, Investment decision and coordination of fresh supply chain blockchain technology considering consumer preference, *Systems*, **12** (2024), 522. <https://doi.org/10.3390/systems12120522>
71. M. Cheng, H. Chong, Y. Xu, H. Wu, Exploring the Determinants of Generative Artificial Intelligence Use Intention: A Mixed Methods Study, *J. Constr. Eng. Manag.*, **152** (2026), 04026091. <https://doi.org/10.1061/JCEMD4.COENG-17763>
72. X. Liang, X. Hu, Green supply chain pricing decision considering blockchain and product recycling, *Comput. Integr. Manuf. Syst.*, **29** (2023), 3851–3868. <https://doi.org/10.13196/j.cims.2022.0443>
73. J. Zhang, What is the role of product services in the dual-channel closed-loop supply chain, *RAIRO-Oper. Res.*, **58** (2024), 3637–3658. <https://doi.org/10.1051/ro/2023183>



AIMS Press

© 2026 the Author(s), licensee AIMS Press. This is an open access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0>)