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BLOCKCHAIN IN SUPPLY CHAIN COLLABORATION: A QUANTITATIVE STUDY

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Abstract
Amid advancements in information technology, this study explores the integration of blockchain technology in supply chain management, particularly for improving collaborative production mechanisms. Known for decentralization, transparency, and data security, blockchain is seen as a solution for issues like information delays and asymmetry in traditional supply chains. To address a gap in empirical research, a model incorporating blockchain for information collaboration in supply chain production management was developed using the Stackelberg game model. Furthermore, a consensus decision model aimed at enhancing supply chain collaboration was established within the blockchain network. These findings provide valuable insights into the practical benefits of blockchain in supply chain management, offering direction for future practice.
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Key Words: Blockchain Technology, Supply Chain Management, Production Management, Collaborative Mechanisms, Stackelberg Game Model, Consensus Decision Model

1. INTRODUCTION

In contemporary industries, blockchain technology has emerged as an object of extensive scrutiny due to its inherently decentralized attributes, high levels of transparency, and robust data security [1-5]. Particularly within the sphere of supply chain management, where the process encapsulates stages ranging from raw material acquisition to production manufacturing and product sales, the potential applications of blockchain are being diligently explored by global corporations and research institutions alike [1-7]. Supply chain management, recognized as a vital business process for today's enterprises, has been found to enhance operational efficiency, curtail operational costs, and amplify the competitive edge of businesses [6-9]. Yet, the inherent complexity and cross-company nature of supply chain management present unique challenges, particularly with regard to information collaboration.

The introduction of blockchain technology into supply chain production management, with its potential to bolster collaborative effects, has been identified as a research area of substantial theoretical and practical import [10-12]. Despite this recognition, substantial challenges are noted in the tasks of quantitatively evaluating the definitive role of blockchain within supply chain management, and the intricate design and implementation of blockchain-centred supply chain collaborative mechanisms [13-16]. Predominant research methodologies have been confined to theoretical examination and case studies, leaving a marked void in the in-depth exploration and quantitative assessment of the specific application ramifications of blockchain within supply chains [17-21]. Such methodological constraints have culminated in a limited understanding and utilization of blockchain's potential in managing supply chains.

In response to this deficiency, the focus of the current research is bifurcated into two principal dimensions. Initially, the construction of a model delineating the effect of information collaboration in supply chain production management, inclusive of blockchain and founded on the Stackelberg game model, is undertaken. This model seeks to furnish a quantitative assessment of blockchain's tangible role in managing supply chain production. In a subsequent stage, the establishment of a consensus decision model for the coordination of supply chain production management contracts, predicated on trust relationships, is executed within the blockchain network of the supply chain. This model is aimed at enhancing efficiency in supply chain collaboration, fostering more coherent production and sales interactions among diverse supply chain participants [20-24]. Through this twofold approach, the practical roles and advantages of blockchain in supply chain management are elucidated, providing fresh theoretical backing and methodological direction. This exploration bears considerable theoretical and practical value, promoting a wider application of blockchain technology within the domain of supply chain management.

2. BLOCKCHAIN-ENHANCED SUPPLY CHAIN COLLABORATION: A SIMULATION MODEL

Blockchain technology has been extensively acknowledged as a pivotal tool with potential to augment the efficiency and transparency of supply chain management. Within the confines of the supply chain, information is perceived as the cornerstone of decision-making, wherein timeliness, accuracy, and integrity are deemed vital to operational efficiency. In conventional supply chain constructs, hindrances frequently surface as a result of fragmented information sharing and time lags, culminating in discord among various interlinked components, thus undermining overall efficacy and benefits.

In contrast, blockchain's capacity to contemporaneously update and authenticate all transactional information is credited with resolving traditional supply chain delays. This includes not only the facilitation of real-time information updates but also the validation of authenticity and the reinforcement of security. Such characteristics have been recognized as essential for the technological underpinning of production management, the orchestration of production activities, and the safeguarded dissemination of production information throughout the supply chain network.

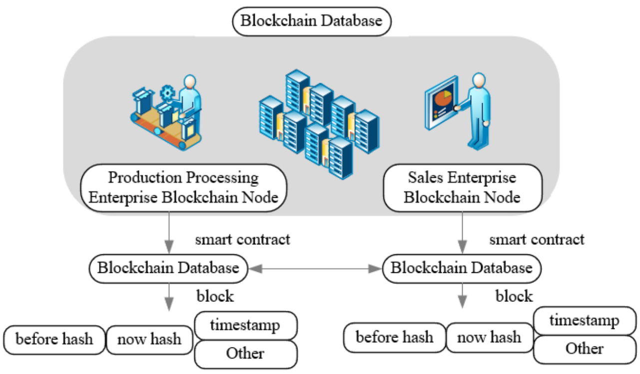

Figure 1: Block structure schematic diagram.

A two-tier supply chain, encompassing both production and processing enterprises, as well as sales entities, serves as the focal point of the present investigation. Insights into the specific influence of blockchain on the supply chain can be gleaned by simulating the product management process of a given commodity (see Fig. 1 for the schematic diagram of the block structure). Employing the Stackelberg game model for modelling and simulation analysis, a quantitative assessment of information collaboration in supply chain production management can be executed. This provides a visual representation of the cooperative advantages bestowed by blockchain-enabled market information timeliness upon conventional supply chain models.

The creation of this simulation model is deemed to furnish an instrumental theoretical apparatus for the quantification of blockchain's impact on supply chain efficiency, thus aiding in the more profound comprehension and application of this technology to further enhance supply chain efficiency and advantages.

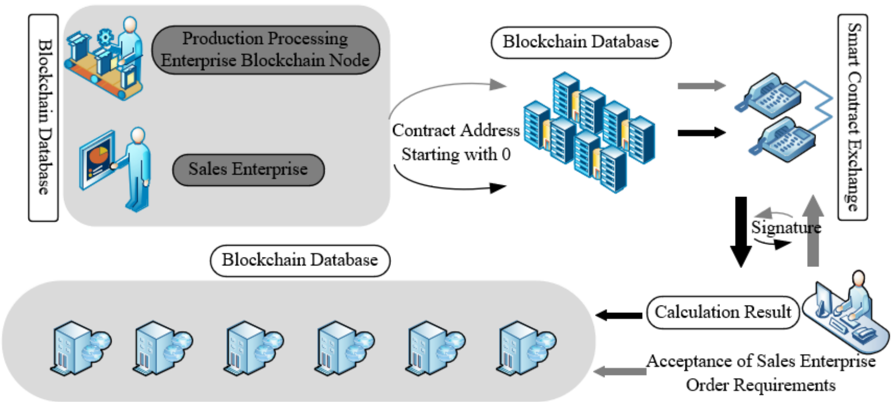

Figure 2: Simulation schematic of supply chain production management information collaboration with blockchain.

Fig. 2 delineates the schematic illustration of the information collaboration simulation in supply chain production management post-blockchain integration. This model is founded on several underlying assumptions: all supply chain participants are considered fully rational, oriented towards profit maximization; subsequent to the blockchain's introduction, all transaction data within the supply chain is to be recorded on the blockchain and rendered accessible in real time to any participant; in the context of the Stackelberg game, one entity (the leader) is presumed to make initial decisions, with others (followers) responding accordingly; within this model, production and processing entities are assumed leaders, with sales entities as followers.

While blockchain technology is recognized to address some trust-related issues, actual supply chain transactions still necessitate a certain degree of trust relationships. Furthermore, the simulation model assumes known key information such as market demand and production costs, thereby reducing complexity and centring the focus on blockchain's impact on collaborative effects.

Assume that the procurement volume of the sales enterprise after the introduction of blockchain is denoted as W^N, and ε represents a loss factor ranging within [0, 1]. The product reliability coefficients before and after the introduction of blockchain are represented by ω and ω^N, respectively. The unit selling price for the sales enterprise is defined as O^N, and the costs for the manufacturing and sales enterprises after the introduction of blockchain are denoted as v_{pa} and v_{pe}, respectively.

Upon the implementation of the blockchain system, data alteration in production management information is inhibited, and dishonest reporting behaviour by the sales enterprise is restrained. Consequently, the costs consumed by both manufacturing and sales enterprises are found to be reduced, that is v_{pa} and v_{pe}:

$$W^N = 1 - O^N + \omega\varepsilon v_{(y)} \tag{1}$$

Profit functions for the manufacturing and sales enterprises are given by the following equations:

$$\Omega_a^N = (C^N - v_a^N - v_{pa})Q^N \tag{2}$$

$$\Omega_y^N = (O^N - v_e^N - v_{pa} - C^N)W^N \tag{3}$$

Using the method of backward induction, the first and second derivatives of W^N are calculated. Since $\beta^2\Pi^N{}_e/\beta^2W^N = -2 < 0$, an optimal solution is found to exist. Setting the first derivative equal to zero, O^{N*} and W^{N*} are derived. Substituting O^{N*} into Eq. (1), and taking the first and second derivatives with respect to C^N, $\beta^2\Pi^N{}_a/\beta^2W^N = -1 < 0$, thereby an optimal solution is found to exist. The optimal sales price for the manufacturing enterprise when implementing blockchain is given by:

$$C^{N*} = \frac{\omega^N \varepsilon v_{(y)} - e_e^N - v_{pe} + v_a^N + 1}{2} \quad (4)$$

Substituting C^{N*} into O^{N*} and W^{N*}, the retail price and optimal order quantity are provided by:

$$O^{N*} = \frac{3\omega^N \varepsilon v_{(y)} - v_e^N - v_{pe} + v_a^N + v_{pa} + 3}{4} \quad (5)$$

$$W^{N*} = \frac{\omega^N \varepsilon v_{(y)} - v_e^N - v_{pe} - v_a^N - v_{pa} + 1}{4} \quad (6)$$

Combining the above formulas, the profit calculation formulas for the manufacturing and sales enterprises after the introduction of the blockchain information platform are obtained:

$$\Omega_a^{N*} = \frac{\left[\omega^N \varepsilon v_{(y)} - v_e^N - v_{pe} - v_a^N - v_{pa} + 1\right]^2}{8} \quad (7)$$

$$\Omega_e^{N*} = \frac{\left[\omega^N \varepsilon v_{(y)} - v_e^N - v_{pe} - v_a^N - v_{pa} + 1\right]^2}{16} \quad (8)$$

The total profit calculation formula for the supply chain is given as:

$$\Omega^{N*} = \Omega_a^{N*} + \Omega_e^{N*} = \frac{3\left[\omega^N \varepsilon v_{(y)} - v_e^N - v_{pe} - v_a^N - v_{pa} + 1\right]^2}{16} \quad (9)$$

Through the simulation model that was constructed, it has been demonstrated that an increase in both the product reliability coefficient ω^N and $\upsilon_{(y)}$ leads to an augmentation in the profits of both supply chain participants and the overall system, thereby facilitating a superior product production management information collaboration effect. Concurrently, when $v_{pa} + v_{pe} < MIN\,(\sigma_1, \sigma_2)$, the incorporation of blockchain technology is found to enhance both the individual profits of the supply chain participants and the collective profit, thus yielding improved collaboration effects.

Analysis of the preceding Stackelberg model exposes the fact that in traditional supply chains without the integration of blockchain, deceptive practices such as concealment of product loss degree and data tampering by the manufacturing enterprise may be present. These practices are shown to harm not only the interests of the sales enterprise but also the overall performance of the supply chain, culminating in suboptimal supply chain production management information collaboration.

Upon the assimilation of blockchain technology, substantial transformations are observed. Due to the immutable and decentralized attributes of blockchain, all transaction information is recorded on the blockchain and made accessible in real-time by all parties, effectively eliminating the dishonest behaviours of the manufacturing enterprise and fostering trust among the members of the supply chain. Moreover, with the utilization of blockchain smart contracts, transactions are observed to be conducted entirely in accordance with preset rules, substantially diminishing human intervention and consequently boosting the efficiency of the supply chain.

3. BLOCKCHAIN CONSENSUS DECISION-MAKING IN SUPPLY CHAIN CONTRACT COORDINATION

In the intricate and dynamically changing landscape of supply chain relationships, the establishment and sustenance of trust relationships have been identified as vital in mitigating conflicts and augmenting cooperative efficiency. Though the immutable and highly transparent characteristics of blockchain systems have been shown to fortify trust amongst various participants within the supply chain, the pragmatic execution necessitates the inception of a supply chain contract coordination mechanism predicated on trust relationships. The objective of this mechanism is the assurance that all participants adhere to the stipulations contained within the contract, thereby enhancing the operational efficiency of the supply chain. Through the formulation of a framework for supply chain production management contract coordination using blockchain consensus decision-making based on trust relationships, the management process within the supply chain can be optimized. Such optimization ensures increased synergism across various links within the supply chain, consequently fostering an improvement in its overall performance.

The construction of a simulation model for supply chain production management contract coordination blockchain consensus decision-making based on trust relationships in this study is mainly divided into three steps: consensus measurement, feedback adjustment, and plan optimization. The purpose of the consensus measurement step is to evaluate the satisfaction assessment values of various supply chain members for contract plans and measure the degree of consensus. The objective of the feedback adjustment step is to identify opinion conflicts and adjust the contract plan to coordinate conflicts and facilitate the achievement of consensus. Finally, based on the first two steps, and by fully considering the overall satisfaction and consensus level of various contract plans, the contract plan with the highest consensus level and satisfaction is selected as the optimal plan, thereby promoting the efficient operation of the supply chain.

Consensus measurement is considered an essential link in constructing a model for supply chain production management contract coordination blockchain consensus decision-making based on trust relationships. This step is mainly to reveal the acceptance level of various supply chain members for different contract plans, as well as the consensus level among the members. In this phase, hesitant fuzzy sets are introduced initially to characterize the evaluators' assessment information. Hesitant fuzzy sets represent a flexible information representation method, effectively expressing the evaluators' hesitancy and uncertainty regarding the evaluation of contract plans. In the specific operation, hesitant fuzzy sets for each contract plan are given under each evaluation criterion based on the evaluators' assessments, followed by certain operations (such as merging, intersection, etc.) to obtain the evaluators' hesitant fuzzy sets for each contract plan. Assuming the hesitant fuzzy evaluation matrix is represented by $G = \{G^j = (g^j{}_{uk})_{l\times b};\ j = 1, 2, ..., l\}$, and the hesitant fuzzy evaluation matrix $G^j = [g^j{}_{uk}]_{l\times b}$ about contract plan S_u under criterion V_u given by decision maker r_j, the following is obtained:

$$G^j = \left[h_{uk}^j\right]_{l\times b} = \begin{bmatrix} g_{11}^j & g_{12}^j \cdots g_{1b}^j \\ g_{21}^j & g_{22}^j \cdots g_{2b}^j \\ \vdots & \vdots \ \ddots \ \vdots \\ g_{l1}^j & g_{l2}^j \cdots g_{lb}^j \end{bmatrix} (u = 1, 2, ..., l; k = 1, 2, ..., b) \tag{10}$$

Given arbitrary two decision-makers, denoted as r_j and r_y, hesitant fuzzy evaluation matrices are represented by G^j and G^y, respectively. The Hamming distance between the two decision-makers regarding the scheme S_u and criterion V_k is expressed by $f(g^j{}_{uk}, g^y{}_{uk})$, with $\#g$ being defined as $MAX(\#g^j{}_{uk}, \#g^y{}_{uk})$. The consensus level $vm^{j,y}{}_{uk}$ of decision-makers r_j and r_y concerning contract scheme S_u under criterion V_k is then given by:

$$vm_{uk}^{j,y} = 1 - f\left(g_{uk}^j, g_{uk}^y\right) = 1 - \frac{1}{\#g}\sum_{m=1}^{\#g}\left|g_{uk}^{j,\delta(m)} - g_{uk}^{y,\delta m}\right| \tag{11}$$

For each contract scheme, satisfaction levels under different criteria must be considered, necessitating the allocation of weights to different criteria. This allocation is usually conducted based on economic considerations, such as cost and efficiency. With the weights for each criterion determined, the consensus level for each contract scheme can be calculated through the combination of weights and decision-makers' evaluations. Fig. 3 illustrates the principles of weight determination simulation based on trust relationships.

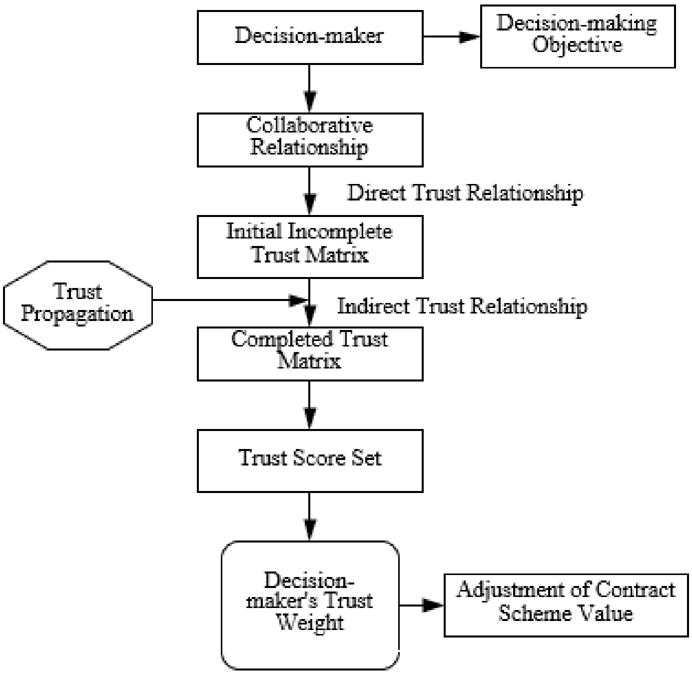

Figure 3: Principle of weight determination simulation based on trust relationships.

If the consensus level of decision-makers r_j and r_y regarding all contract schemes is represented by $\Delta(r_j, r_y)$, then:

$$\Delta(r_j, r_y) = \sum_{u=1}^{l} \eta(S) \cdot \sum_{k=1}^{l} \eta(V) \cdot vm_{uk}^{j,y}, j, y = 1, 2, \ldots, l \tag{12}$$

where $0 < \Delta(r_j, r_y) < 1$, if $\Delta(r_j, r_y)$ is less than the initial consensus threshold ϕ, a divergence of opinion between decision-maker r_j and decision-maker r_y to a certain extent is indicated.

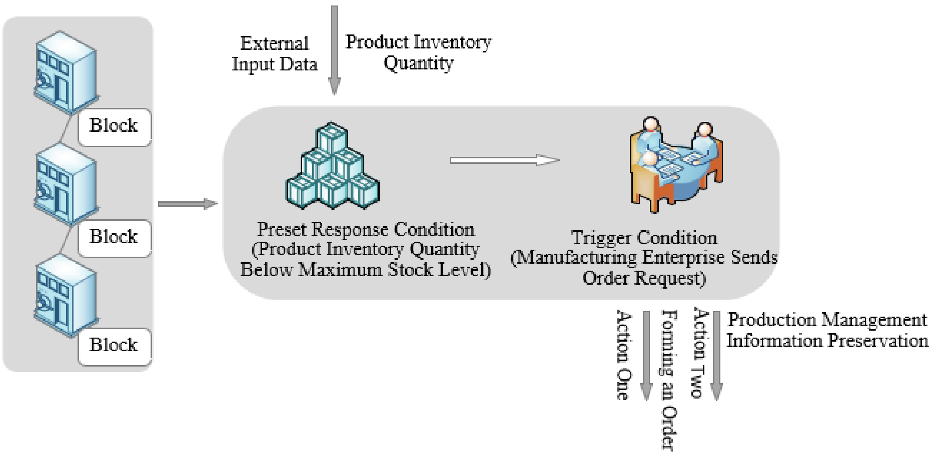

Figure 4: Process of contract scheme execution within a block.

Fig. 4 depicts the process of executing contract schemes within a block. Ultimately, the consensus level of the group can be generated based on the consensus levels of individual contract schemes. The group consensus level serves as an overall indicator, reflecting the acceptance degree of the entire supply chain members towards various contract schemes. If the group consensus level is high, it signifies a greater acceptance and consensus degree among supply chain members concerning the contract schemes, which is beneficial to the operation of the supply chain. The group consensus level HVM is then given by:

$$HVM = \underset{j,y=1,\ldots,l}{MIN} \{\Delta(r_j, r_y) | j, y = 1, 2, \ldots, l\} \tag{13}$$

4. ANALYSIS OF SIMULATION RESULTS

As depicted in Fig. 5, an escalation in product quality reliability was found to correspond with an enhancement in profits for both manufacturing and sales entities within the supply chain. Such an association was elucidated by the augmented attraction of customers towards higher quality products, culminating in increased sales and diminished expenses linked to returns and repairs emanating from quality deficiencies. Furthermore, it was observed that the growth in profits of both the sales and manufacturing sectors symbolizes an overall enhancement in the efficiency of the supply chain. Upon the integration of blockchain technology, a more pronounced increase in profits was noticed within the sales companies as compared to manufacturing firms. This phenomenon was attributed to the sales companies' direct interaction with consumers, making the escalation in product quality reliability more substantially influential on sales. Meanwhile, even though profit growth within manufacturing companies was not as marked, an evident augmentation in profit was nonetheless detected subsequent to the integration of blockchain, thereby highlighting the efficacy of blockchain in assuring product quality, curtailing production loss, and escalating production efficiency.

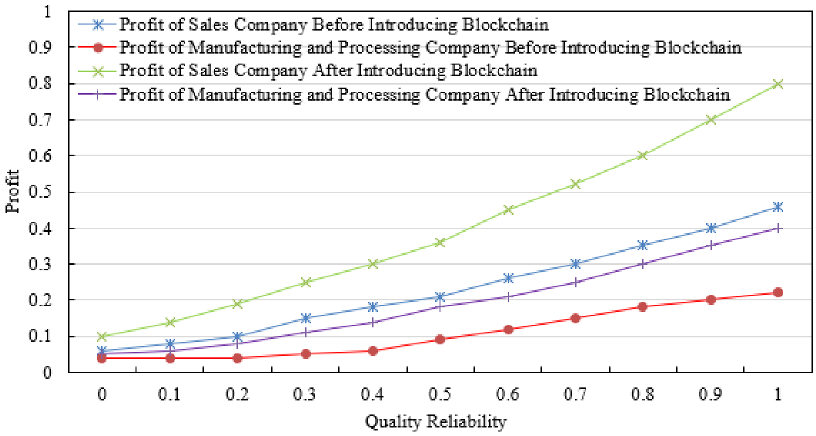

Figure 5: Relationship curve of profit and product quality reliability for manufacturing and sales companies.

In Fig. 6, fluctuations in order quantity were discerned concomitant with augmentations in production and sales cost, independent of the presence of blockchain technology. When blockchain technology was employed, a decline in order quantity in response to escalated costs was documented. This trend was explicated by blockchain's capability to proffer transparent, real-time insights into supply chain data, facilitating a clearer understanding of cost structures. Consequently, there was a propensity to curtail order quantity under elevated costs to mitigate risk and expenditures. This observation underscored the value of blockchain in the enhancement of supply chain efficiency and decision optimization. Simultaneously, it was noted that the order quantity post-blockchain remained superior to pre-blockchain levels, even with surging costs. This tendency was ascribed to the trust and confidence engendered within the supply chain by blockchain's attributes of information transparency and smart contract functionalities.

In this study, the actual range of values for the parameters on the x and y axes in Figs. 6 to 8 are normalized to [0, 1]. The purpose of normalization is to transform data of different scales and units to a uniform standard, facilitating comparison and understanding. Furthermore, as the model constructed is highly sensitive to the scale and distribution of the input data, normalization can enhance the convergence speed and accuracy of the algorithm. Moreover, when dealing with data from multiple sources or with different scales and units, such as quality reliability-profit, cost-order quantity, and cost-product price, normalization aids in integrating and aligning the data, thereby ensuring the consistency and accuracy of the overall analysis.

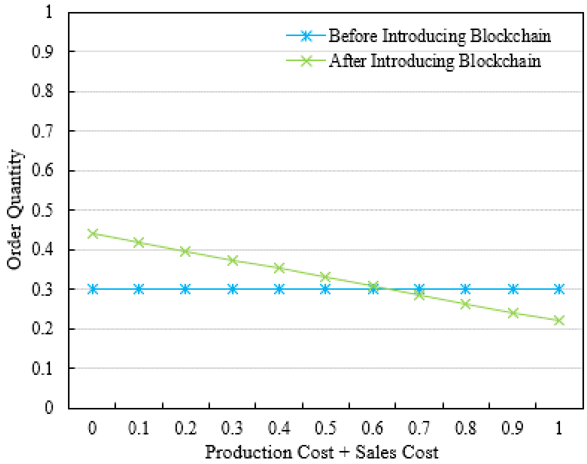

Figure 6: Relationship curve of business investment cost and order quantity.

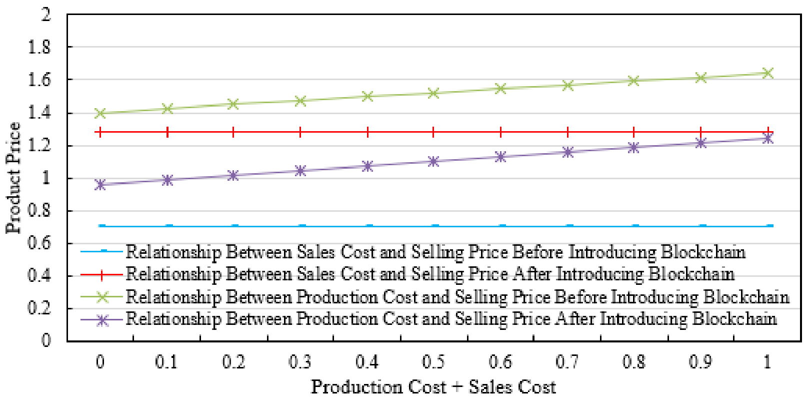

Figure 7: Relationship graph of investment cost and price for sales and manufacturing companies.

As detailed in Fig. 7, substantial transformations in the nexus between investment cost and price for sales and manufacturing firms were detected following the introduction of blockchain technology. Post-integration, discernible shifts were identified in the relationships between sales cost and selling price, along with production cost and selling price. While the linkage between sales cost and selling price remained constant, a conspicuous elevation in the selling price was discerned, relative to pre-blockchain benchmarks. This occurrence was correlated with the transparency and efficiency fostered by blockchain technology, permitting companies to inflate selling prices within a more extensive bracket, thereby consolidating greater profits. Concurrently, a positive affiliation between production cost and selling price was revealed post-integration, characterized by a gradual inflation in selling price concomitant with an upsurge in production cost. This alteration was rationalized by blockchain's ability to permit accurate cognizance of shifts in production cost and the ensuing immediate adaptation of selling prices to conserve profit margins.

In the context of consensus decision-making in supply chain contract coordination founded on trust relationships, several strategies were examined; five emblematic schemes were selected for experimental comparison within this study.

Scheme 1: A reputation scoring system was instituted, where scores reflecting credibility were assigned based on historical performance and adherence to contracts.

Scheme 2: Regular trust education and communication were conducted, fostering understanding and trust formation.

Scheme 3: An open and transparent information-sharing platform was devised, employing blockchain technology for comprehensive supply chain information sharing.

Scheme 4: An autonomous consensus decision-making body was established.

Scheme 5: A risk-sharing mechanism was implemented. All these strategies were oriented towards the refinement of coordination and consensus decision-making in the supply chain via the reinforcement of trust relationships, thereby augmenting overall efficacy and advantages.

Table I: Scores of individual and collective solutions in production management consensus decision-making.

Decision-maker	Score (corresponding to 5 solutions)
Collective	(0.7625, 0.6824, 0.7548, 0.7335, 0.7746)
Decision-maker 1	(0.6846, 0.7312, 0.7215, 0.6412, 0.7326)
Decision-maker 2	(0.7815, 0.7215, 0.7025, 0.7625, 0.7811)
Decision-maker 3	(0.8231, 0.6458, 0.8612, 0.7788, 0.8918)
Decision-maker 4	(0.8142, 0.7133, 0.7561, 0.8322, 0.7815)
Decision-maker 5	(0.8123, 0.6326, 0.7841, 0.7221, 0.8152)

In Table I, an examination of individual and collective scores pertaining to production management consensus decision-making schemes is presented. Computation of the total score for each scheme was performed by aggregating the individual decision-makers' scores and the collective score. The overall scores yielded the following results: 4.6782 for Scheme 1, 4.1268 for Scheme 2, 4.5802 for Scheme 3, 4.4703 for Scheme 4, and 4.7768 for Scheme 5. Through this computation, a ranking was determined as follows: Scheme 5 > Scheme 1 > Scheme 3 > Scheme 4 > Scheme 2. In the context of consensus decision-making in supply chain contract coordination based on trust relationships, Scheme 5 was identified as the optimal solution, while Scheme 2 was concluded to be the least optimal solution. It was deduced that risk-sharing mechanisms could foster trust and collaboration efficiency within supply chain management more effectively, whereas reliance on mere training and communication was shown to be less fruitful.

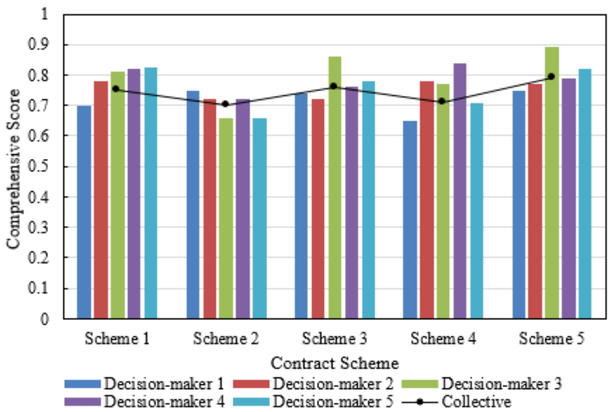

Figure 8: Scores of individual and collective solutions in production management consensus decision-making.

Fig. 8 offers an illustration of the individual and collective scores of production management consensus decision-making schemes, corroborating the results presented in Table I. The overall scores for the schemes were calculated to be consistent with Table I. Hence, it was concluded that Scheme 5, encompassing strategies such as risk-sharing mechanisms and supply chain transparency enhancements, emerged as the most effective in cultivating trust and collaboration efficiency among parties. In contrast, Scheme 2, relying on conventional management techniques, was discerned to be less effective.

According to Fig. 9, an analysis of losses under each scheme for individual decision-makers and the collective was conducted. Representation of loss values by negative numbers indicated failure or deficit under the respective scheme, with a larger negative score signifying a greater loss. An evaluation of the total losses of each scheme was performed by summing the loss values. Scheme 2 was found to have the smallest total loss, whereas Scheme 1 incurred the largest total loss. Hence, Scheme 2 was acknowledged as the least risky, and Scheme 1 was considered the riskiest. This was attributed to Scheme 1's inconsistent performance, leading to the largest aggregate loss, whereas Scheme 2's minimal loss resulted in the smallest total loss. Therefore, Scheme 2 was denoted as the optimal choice concerning losses, and Scheme 1 was identified as the least favourable option.

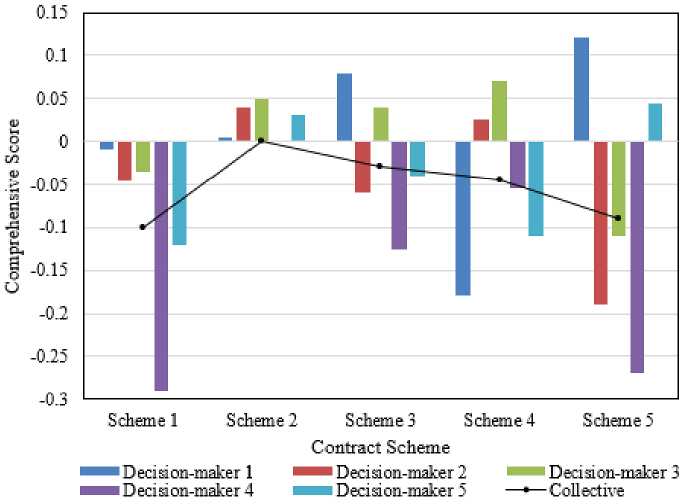

Figure 9: Scores of individual and collective solutions in production management consensus decision-making considering losses.

Table II: Final results of trust weights and scores of production management consensus decision-making solutions.

Scheme	**Scheme score**		**Decision-maker**	**Trust weight**	
	Without considering loss	**Considering loss**		**Without considering loss**	**Considering loss**
Scheme 1	0.7615	-0.1008	Decision-maker 1	0.41	0.15
Scheme 2	0.6821	0.0025	Decision-maker 2	0.12	0.24
Scheme 3	0.7789	-0.0231	Decision-maker 3	0.18	0.18
Scheme 4	0.7233	-0.0415	Decision-maker 4	0.13	0.19
Scheme 5	0.7782	-0.0887	Decision-maker 5	0.24	0.26

In Table II, an intricate analysis of each scheme's scores, together with the trust weights designated by each decision-maker, was performed. This consideration included scenarios with and without consideration of losses. Without the loss consideration, higher scores for Schemes 3 and 5 were observed. However, with losses considered, only Scheme 2 scored positively. A complex interplay between scheme scores and decision-makers' trust weights was noted, necessitating a nuanced understanding of these variables. Ultimately, Scheme 2 was pinpointed as optimal, although adjustments in the trust weight for Scheme 2 by the relevant decision-makers were suggested to be necessary.

5. CONCLUSION

Within the scope of the content explored in this research, the development of a blockchain-based model for consensus decision-making in supply chain production management contract coordination has been rigorously addressed. Optimization and coordination of disparate links within the supply chain were achieved in a structured three-step process: consensus measurement, feedback adjustment, and scheme preference selection. By means of evaluating parameters such as individual satisfaction values, consensus measurement, and trust weights within the supply chain, contract terms that were characterized by a diminished level of consensus were systematically identified. Consequently, a trust weights-based feedback mechanism was constructed, and the facilitation of coordination among conflicting opinions was realized, culminating in the selection of an optimal scheme. Through experimental data analysis, it was demonstrated that the devised model is capable of effectively coordinating multiple decision-makers, orienting decisions towards maximizing collective profit.

A further analytical dimension was added by conducting a comparative evaluation of principal economic indicators, including profit, order quantity, cost, and selling price of sales and production processing companies, both pre- and post-blockchain integration. The simulation of data revealed that subsequent to the incorporation of blockchain, appreciable enhancements in profits and order quantities across various enterprises were observed. Simultaneously, a significant diminution in the ratio of production and sales costs to selling price was detected.

In a comprehensive assessment of the research, it was found that the approach was both methodologically profound and systematically executed. The design of the model was ascertained to be conducive to the supply chain's efficient operation. The meticulous construction of the experimental section, coupled with a lucid analysis of the outcomes, provided a robust validation of the model's practical applicability.

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