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Blockchain for Mass Customization: The Value of Information Sharing Through Data Accuracy by Contract Coordination

Zhening Ye [1,2], Jie Wang [1] and Huida Zhao [3,4,*]

[1] Transportation Engineering College, Dalian Maritime University, Dalian 116026, China; yehchening@gmail.com (Z.Y.); dlwjie@163.com (J.W.)
[2] Department of Maritime Sciences, Kobe University, 5-1-1 Fukaeminami-machi, Higashinada-ku, Kobe 658-0022, Japan
[3] College of Management, Shenzhen University, Shenzhen 518061, China
[4] Shenzhen International Maritime Institute, Shenzhen 518083, China
* Correspondence: lskjd003@gmail.com

Abstract: This study provides the game-theoretical framework to investigate the relationship between the blockchain service and mass customization in the environment of information sharing and contract coordination. Specifically, we construct the game-theoretical models of the manufacturer and the retailer to discuss the optimal strategy of information sharing by the retailer in the case of mass customization. The result explores the conditions of information sharing for the retailer because she understands the end market information of nearby consumers. This discussion helps us to understand that the motivation of the manufacturer pays for the retailer's construction of a blockchain system in the case of two types of products, such as a standard product and a customization product. Finally, we use the method of contract coordination to obtain the optimal strategy. Results reveal that information costs significantly impact sharing decisions, and cost-sharing contracts can incentivize retailers to share market data. This study has two main contributions. On the one hand, this study adopts the blockchain service for mass customization by supporting contract coordination, showing the technical value of avoiding false information and tampering-proof. On the other hand, although big data has the same information sharing function, this technology can't play the role of secure data transmission. In order to increase the accuracy of information sharing, we analyze the fusion results of two technologies in the aspect of increasing the accuracy of data sharing, which better reveals the technical value.

Keywords: mass customization; information sharing; blockchain service; contract coordination; relevant stakeholders

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1. Introduction

1.1. Background and Motivation

The emergence of blockchain services has promoted changes in the production mode, increased the flexibility of the production process, and reduced the problem of limited production quantity of the product line [1,2]. Crucially, this change can enable mass customization in supply chain activities [3]. As one of the production modes, mass customization allows the customers to design a product according to their needs while keeping costs closer to those of the mass-produced products [4–7]. Therefore, a key distinction between mass customization and traditional production lies in its dependence on personalized consumer data, which guide production and marketing decisions after customer needs are specified [8].

Retailers at the forefront of consumer interaction have a natural advantage in collecting and understanding detailed market information, such as preferences, purchasing behavior, and demand trends. However, despite the strategic importance of such data, information sharing between retailers and manufacturers often faces significant challenges [9]. These challenges arise from differences in perceptions of data ownership, concerns about data privacy, and the costs associated with data sharing. Retailers may also fear losing their competitive advantage if critical market insights are disclosed to manufacturers. Consequently, this lack of trust and alignment between supply chain participants undermines the efficiency of mass customization processes.

Blockchain technology offers a robust solution to these challenges. It has key features that can enhance data security and reliability, including immutability, transparency, and decentralized trust, thereby fostering trust in information sharing [10]. By leveraging blockchain services, manufacturers can create a secure and tamper-proof environment for sharing sensitive consumer data, addressing retailers' concerns about data misuse or accuracy. Moreover, blockchain-enabled smart contracts can be used to design innovative cost-sharing mechanisms and align the interests of both parties, ensuring that retailers are adequately incentivized to share information, such as mixed technologies.

In traditional customized production, there are some problems related to the security and reliability of information transmission. Furthermore, data transmission between humans and machines is insufficient [11]. Compared with this, blockchain services can increase the security and credibility of information sharing. However, the manufacturer may be hesitant to obtain customized data from retailers to gain a market advantage [12]. Rather, by providing blockchain services to retailers, manufacturers can gain information superiority and, thus increase market efficiency. Therefore, due to the dynamic and profitable information, they need a reasonable contract to realize information sharing between both parties. This study investigates the potential of blockchain technology to enable more effective collaboration in mass customization supply chains. Specifically, this study seeks to answer the following critical questions:

Question 1: What is the impact of the information cost on the sharing behavior via blockchain services under mass customization?

Question 2: How can a manufacturer achieve reasonable contract coordination using the retailer's market information to obtain benefits?

Question 3: How can a manufacturer's positive interests be realized through new technology (such as big data)?

1.2. Major Findings

To answer the aforementioned questions, we construct a game-theoretical model to explore the optimal strategy for information sharing via supporting blockchain services in a mass customization environment. Our main results are as follows:

First, this study investigates the influence of information costs on sharing behavior. The results show that the retailer must pay an information cost for each product when sharing information. In other words, nothing can be carried out too early. The retailer's information sharing behavior increases the cost of the unit product.

Second, if the retailer does not receive any benefits from the manufacturer, it will not share the information on the terminal market. Instead, through contract coordination between themselves, the manufacturer and the retailer can achieve the goal of information sharing and obtain benefits from the cost-sharing contract, discount coupons, and wholesale price discounts.

Finally, we analyze the stability of the results from different aspects, including unreal product quantity in information sharing, changes in the utility function in the baseline analysis, optimal strategy in the case of an uncovered market, optimal strategy in the case of a product with a delay strategy, and optimal strategy with additional new technology. By supporting blockchain services and big data technology, these discussions can increase our understanding of mass customization information sharing.

1.3. Contribution Statement, Feature, and Structure

The contributions of this study are twofold: On the one hand, this study adopts the blockchain service for mass customization by supporting contract coordination, which shows the technical value of avoiding false information and tampering. This highlights the relationship between blockchain services and mass customization. On the other hand, although big data has the same function as information sharing, this technology cannot play a role in data security transmission. To improve the accuracy of information sharing, this study analyzes the effects of two technologies on improving the accuracy of data sharing in a mass customization environment, thus better revealing the value of these two technologies.

This study has two main features. First, this study considers blockchain services in mass customization to increase the accuracy of information sharing, thus highlighting the technical value of these services. Specifically, we demonstrate that this service mode improves the customer experience by helping firms to better meet customers' shopping needs. Second, this study considers supply chain cooperation through contract design. We find that blockchain technology can improve information accuracy while reducing the proportion of false information, thereby highlighting the value of blockchain in avoiding false problems.

The structure of this paper is as follows: Section 2 presents the literature review. Section 3 introduces the model setting. Section 4 constructs our basic analysis from different aspects of the equilibrium, including the influence of blockchain technology on different factors, the influence of information cost on sharing behavior, profits for different shareholders, and contract coordination for the equilibrium strategy. Section 5 makes some extensions by considering the cases of unreal product quantity in information sharing, changes in the utility function in the basic analysis, optimal strategy in the case of the uncovered market, optimal strategy in the case of a product with a delay strategy, and optimal strategy in the case of additional new technology. Some results are discussed in Section 6. Finally, the relevant conclusions and management implications are presented in Section 7. To show the results, we offer brief proofs of the propositions in the Appendix B.

2. Literature Review

We review the related literature, including mass customization, information sharing, and contract coordination, and then discuss the research gap.

2.1. Mass Customization in Supply Chain Management

Here, we discuss mass customization in the literature. Specifically, we review the literature to find related content that describes mass customization in supply chain management. Among extant studies, Kouhpayeh et al. investigate the role on the trust-building element in the marketing activity by the support of blockchain technology [13]. Qu et al. propose a framework of asynchronous federated learning with blockchain technology in order to promote markets' shift toward mass customization [14]. Guo et al. explore the application of 3D printing in mass customization projects [15]. Yetis et al. propose a reliable and optimized framework for mass customization to fully exploit the positive role of blockchain, the Internet of Things, and cyber-physical systems in adopting a personalized customization production mode [1]. Jain et al. attempt to establish a theory of mass customization in manufacturing units [16]. Longo et al. propose a two-stage design process based on a platform to support clothing brands in implementing mass customization strategies [17]. Qi et al. empirically examine the influence of lean and agile practices, mass customization, and product innovation capability on service implementation [18]. Shao develops an analytical model to study the optimal production strategy for mass customization in a market in which customers have different preferences for product types [19]. Wu et al. reveal the important responsibility and role of information-sharing practices in coordinating suppliers' modular practices [20].

Overall, our study is most closely related to that of [1], who analyze the relationship between mass customization and blockchain services. However, few quantitative studies have examined this relationship. Here, we consider the information-sharing value of blockchain services in mass customization, similar to [20]. Furthermore, in the aspect of mass customization, blockchain could increase the trust foundation of trusted customers. Our research is more about the trust of blockchain under information sharing.

2.2. Information Sharing with Blockchain Service

Next, the literature demonstrates the technical value of information sharing via blockchain services. For example, Qu et al. study a new framework of information sharing with an asymmetric encryption transmission method by the support of blockchain technology [21]. Xu et al. use the game-theoretical model to analyze the role of information sharing by blockchain technology in the case of offline and e-platform channels under the cap-and-trade scheme, which shows the technical value of traceability and high transparency [22]. Zheng et al. study the risk decision-making problem faced by spacecraft supply chain participants based on information sharing via blockchain services [23].

Taking advantage of blockchain services in information recording and sharing, Du et al. propose a new business process and construction scheme for a medical information-sharing platform based on blockchain services [24]. Dwivedi et al. design a scheme based on blockchain services to securely share information in a pharmaceutical supply chain system using an intelligent contract and consensus mechanism [25]. Wang et al. propose an information management framework for prefabrication supply chains based on blockchain services, which is helpful for the timely delivery of prefabricated components and tracking the causes of disputes related to these components [26].

Based on theoretical research on supply chain information asymmetry and collaboration, Si et al. analyze the lightweight security framework for information sharing via the Internet of Things based on blockchain technology and a dynamic game method of node cooperation to prevent malicious acts of local domination [27].

Although some studies analyze the necessity of blockchain technology in information sharing, few studies highlight the useful conditions for blockchain services in an environment of information sharing for supply chain members, especially the tamper-proof and accuracy characteristics of blockchain services. Our study explores the condition of using blockchain technology in the case of information sharing, which could show the value of blockchain technology on the environment of supply chain activity.

2.3. Contract Coordination in Supply Chain Management

The literature discusses various types of contracts, including cost sharing, delay, and revenue-sharing contracts. For example, Crettez et al. study how to coordinate the benefits of vertical supply chain members through a revenue sharing contract with wholesale price and fixed sales revenue share [28]. Quadir et al. investigate the result that sharing demands information in competing supply chains with greening efforts [29]. Gago-Rodríguez et al. (2021) discuss the extent to which asymmetric bargaining power among supply chain members mitigates the impact of environmental delay costs on negotiation results [30]. Hosseini et al. (2021) investigate the effects of discounts and advertisements on aggregate demand and profits in the ecotourism supply chain [31]. Zhang et al. compare the optimal green decision and profit under a single- or dual-channel strategy with and without green investment, and determine the optimal channel strategy for the supply chain under prepayment financing [32]. He et al. use cost allocation to explain that consumers' low-carbon preference, the marginal profit of chain members, and corporate social responsibility behavior significantly influence the optimal solution [33].

To optimize the revenue of supply chain members under decentralized decision making, Wu et al. construct a revenue-sharing contract between a recycling center and a third-party recycler and, finally, realize the overall coordination of the supply chain [34]. Considering the reference emissions and cost-learning effects, Yu et al. study Stackelberg differential games with manufacturers as leaders and retailers as followers [35]. Wang et al. indicate that implementing a cost-sharing contract can improve the carbon emission reduction level, product quantity, and supply chain profit [36]. Fan et al. study the impact of the product liability cost allocation mechanism caused by quality defects on product quality and pricing decisions, and the equilibrium profitability of supply chain members and the entire supply chain [37]. Gilotra et al. discuss the impact of human error checks on emissions costs, transportation costs, and deferred payments in inventory management [38]. Raza et al. propose a supply chain coordination scheme for pricing inventories and a corporate social responsibility investment decision for a single manufacturer–retailer supply chain [39].

Yet, there is little discussion on contract coordination in the case of information sharing via supporting blockchain services. Here, we reveal the value of contract coordination for information sharing via the use of blockchain services in supply chain management.

2.4. Discussion of the Existing Literature

The literature review shows that, first, mass customization helps improve customer experiences rather than standard production. However, it is difficult to obtain timely and accurate market information for mass customization, such as customer habits and shopping experiences. Here, the emergence of blockchain services can alleviate this situation by providing supporting technical features, such as tamper prevention and timeliness. Indeed, extant studies rarely consider the relationship between blockchain services and mass customization based on quantitative research. Here, we explore the conditions for using blockchain services to improve the usefulness of information sharing.

Second, while studies have considered contract coordination in supply chain management, few have investigated the impact of contract coordination on blockchain service applications, particularly for different types of contract coordination. Meanwhile, we discuss contract coordination between mass customization and blockchain services in information sharing. This provides a reasonable strategy for applying blockchain services. In summary, we provide specific conditions for implementing blockchain services in information sharing. The results reveal the practical value of blockchain services in mass customization.

3. Model

3.1. Scenario Description

Consider a supply chain with a manufacturer and retailer each. The retailer enjoys market superiority due to it being near the end market. Thus, it can capture more information about customers, such as their shopping preferences and search habits. Correspondingly, the manufacturer can obtain market information from the retailer's information sharing via contract coordination. However, the retailer has the right to decide whether to share the market information with the manufacturer. If the retailer chooses exclusive market information, the scenario is marked N as a strategy. Otherwise, the scenario is marked Y, representing the strategy when the retailer shares market information. To obtain the optimal strategy of information sharing by firms, we consider the following types of contracts: cost-sharing contract (strategy Y-C), discount coupons (strategy Y-S), and discount of wholesale price (strategy Y-D).

Next, we also consider two types of products: standard product A and customized product B. Specifically, the manufacturer produces two types of products. For a standard product, the manufacturer can use their own market data to determine the production plan. Meanwhile, for customized products, they need data from customers to determine how to produce products to satisfy customer requirements in a mass customization environment. Finally, based on the product characteristics, the retailer sells these two types of products in the market.

3.2. Model Assumptions

We make some assumptions in our analysis:

(1) According to the literature [40,41], the retailer offers two types of products to end consumers. Specifically, the consumers' perceived value is V; their utility from standard product A and customized product B offerings are $U_A = V - p_A$ and $U_B = \theta V - p_B + t$, respectively. Note that the decision variables p_A and p_B are the two types of product prices in the environment of standard production and mass customization, respectively. The parameter $\theta \in (0,1)$ represents the valuation difference between products A and B. This design is based on product A to analyze the competitive relationship between customized products and standard products. Finally, the parameter t represents the accuracy level of data sharing by the blockchain system supporting retailer.

(2) The retailer has access to a demand signal Γ_i, which is an unbiased estimator Y, and decides whether to share it with the manufacturer before the demand is observed. According to [42,43], the signal accuracy is defined as t and demand is forecasted as follows: $E[Y \mid \Gamma_i] = E\left[\Gamma_j \mid \Gamma_i\right] = \frac{t_i \sigma^2}{1 + t_i \sigma^2} \Gamma_i$. σ is the variance of market information. This information structure is common knowledge.

(3) Following the literature, we consider that the service cost involves an operational cost of the unit product (kt) and an investment cost (at^2) [44–46]. The parameters k and a belong to the cost parameter, which satisfy with $k, a \in (0,1)$. Specifically, we set $a = 1$ to show the main discussion. Moreover, retailers choose to invest directly in blockchain technology to ensure the transparency of the supply chain, reduce the problem of counterfeit goods in the supply chain, and improve the trust of consumers. For example, JD company has also achieved a lot of explorations in the application of blockchain technology, especially in supply chain management, commodity traceability, and anti-counterfeiting. It has developed its own blockchain system to strengthen its control and traceability of commodity quality, avoid the circulation of counterfeit goods, and ensure that consumers can obtain real information.

(4) We assume rational economic agents who maximize their benefits to obtain maximum benefits or maximum consumption experience.

3.3. Utility and Profit Functions

We consider two scenarios where in the retailer does (N) and does not share information (Y). In the basic model, the model settings of the two scenarios are the same. Different from non-information sharing, information sharing is influenced by market signals Γ_i. To express the model clearly, the utility functions of two products are designed as follows:

$$U_A = V - p_A \tag{1}$$

$$U_B = \theta V - p_B + t \tag{2}$$

The profit function expressions of the retailer and manufacturer are as follows:

$$\pi_R = (p_A - w_A)q_A + (p_B - w_B - kt)q_B - t^2 \tag{3}$$

$$\pi_M = w_A q_A + w_B q_B \tag{4}$$

$$\pi_{SC} = \pi_M + \pi_R \tag{5}$$

The wholesale prices of the two products are w_A and w_B. Correspondingly, the product quantities are q_A and q_B, respectively. Finally, according to whether information sharing is introduced, the corresponding model superscript is marked in the model, such as π_R^N and π_M^N.

3.4. Decision Sequence

The decision sequence is as follows: First, the manufacturer determines the wholesale price for the two types of products. Second, the retailer considers whether to adopt information sharing. Moreover, according to the retailer's information-sharing behavior, the retail prices of the two types of products can be considered. Finally, the market is cleared.

4. Basic Analysis

Here, we discuss four aspects: the influence of blockchain technology on different factors, the influence of information costs on sharing behavior, profits of different shareholders, and contract coordination of the equilibrium strategy. These discussions reveal the value of blockchain services in information sharing and contract coordination under mass customization.

4.1. The Influence of Blockchain Technology on Different Factors

We first examine the influence of blockchain services on various factors under mass customization, including the wholesale price, retail price, and product quantity. The results are shown as the following Lemma 1.

Lemma 1 (influence of blockchain services on different factors)**.**

(1) *The impact of blockchain services on the wholesale price:*

$$\frac{\partial w_B^N}{\partial t} > 0;\ \frac{\partial w_B^Y}{\partial t} > 0;\ \frac{\partial w_B^N}{\partial \Gamma} = 0;\ \frac{\partial w_B^Y}{\partial \Gamma} > 0$$

(2) *The impact of blockchain services on the retail price:*

$$\frac{\partial p_B^N}{\partial t} > 0\,;\ \frac{\partial p_B^Y}{\partial t} > 0\,;\ \frac{\partial p_B^N}{\partial \Gamma} > 0\,;\ \frac{\partial p_B^Y}{\partial \Gamma} > 0$$

(3) *The impact of blockchain services on the product quantity:*

$$\frac{\partial q_B^N}{\partial t} > 0\,;\ \frac{\partial q_B^Y}{\partial t} > 0\,;\ \frac{\partial q_B^N}{\partial \Gamma} = 0\,;\ \frac{\partial q_B^Y}{\partial \Gamma} > 0\,.$$

The Lemma 1 illustrates the value of a blockchain services. Specifically, the wholesale price increases with the accuracy of data activity regardless of information sharing in the supply chain system. Moreover, the demand signal has a positive effect in the case of information sharing, increasing the wholesale price. These changes show the value of the blockchain services through a change in the unit price. Specifically, it can result in a high wholesale price without considering the manufacturer's unit cost. Similarly, it shows the results for the retail price and product quantity with blockchain services. Furthermore, these results show similar trends, revealing the value of blockchain services in terms of data accuracy and demand signals. Thus, blockchain services increase the factor values of mass customization through the wholesale price, retail price, and product quantity.

4.2. The Influence of Information Cost for Sharing Behavior

Next, we consider the influence of information costs on sharing behaviors. Specifically, we define a term $c_B^j\left(j = N, Y\right)$, which can be written as $c_B^j = t^2 \big/ q_B^j, \left(j = N, Y\right)$. This term describes the information cost of a unit product under a blockchain service considering the impact of data accuracy and demand signals. The results are presented in Proposition 1.

Proposition 1 (information cost of unit product).

(1) $c_B^N = \dfrac{4t(1-\theta)\theta\left(1+t\sigma^2\right)}{1-k+\left((1-k)t+2\Gamma(1-\theta)\theta\right)\sigma^2}\,;\ c_B^Y = \dfrac{4t(1-\theta)\theta\left(1+t\sigma^2\right)}{1-k-\left((1-k)t+\Gamma(1-\theta)\theta\right)\sigma^2}\,.$

(2) $c_B^N < c_B^Y$.

Proposition 1 shows the information cost of a unit of product in the two cases. Based on the definition of information cost per unit product, we can obtain the results of two information-sharing models in the supply chain: with and without information sharing. The result shows that $c_B^N < c_B^Y$, which can be referred to in Appendix B.1. This indicates the higher cost with information sharing. This may explain why firms do not want to share information with others, as it can increase the unit product cost. This also indirectly decreases the benefits of the unit product and product price. Therefore, from the perspective of the unit cost of information sharing, firms prefer not to share information to obtain superiority in terms of product price. To obtain a potential strategy for information sharing via blockchain services, we can further consider the changes in firms' profits.

4.3. Profits for Different Shareholders

Next, we discuss the changes in the profit for firms to find the optimal strategy. The result is shown as Proposition 2 by analyzing the profits of firms and total the profit for the supply chain.

Proposition 2 (comparison of the profit for firms). $\pi_R^N > \pi_R^Y\,;\ \pi_M^N < \pi_M^Y\,;\ \pi_{SC}^N > \pi_{SC}^Y\,.$

Proposition 2 presents the results of the analysis for profit changes. Specifically, $\pi_R^N > \pi_R^Y$ and $\pi_M^N < \pi_M^Y$ indicate the firms' different choices, which can be referred to in Appendix B.2. The manufacturer would like to share information to obtain greater profits and consumer quantity. However, the retailer does not prefer information sharing. Thus, the retailer can obtain superior information from consumers in the process of a mass customization promotion.

Additionally, from the perspective of the equilibrium strategy, the results show two cases. On the one hand, the profits of the retailer and supply chain remain consistent in the optimal strategy. On the other hand, the profits of the manufacturer are inconsistent. Thus, a feasible strategy needs to explore new solutions to meet the interests of the manufacturer, retailer, and supply chain. Therefore, in Section 4.4, we further explore a reasonable solution through the three types of contract coordination.

4.4. Contract Coordination for the Equilibrium Strategy

Here, we consider three types of contract coordination to find the solution for the equilibrium: the cost-sharing contract, discount coupons, and wholesale price discount.

4.4.1. The Cost-Sharing Contract

Here, we change the profit function using a cost-sharing contract. Specifically, contract design is based on how information transmission happens. For example, the retailer has its own blockchain information system to support business needs, such as customer and process management, by closing the end market. The manufacturer needs to pay some costs to the retailer to obtain market information or customer information to stay away from the market, which is especially unfavorable in a mass customization environment, such as price design [40]. Therefore, to design the production plan, the manufacturer pays the retailer the cost of acquiring correlative information from the retailer's information system, which shares information in the blockchain system with the permitted supply chain.

Based on the above, we have changed the profit function with the cost parameter m_B^{Y-C} to share the technical cost based on the existing models. This cost parameter changes in the technical investment cost $m_B^{Y-C}t^2$ for the retailer in the case of information sharing (Y). Moreover, the manufacturer incurs the cost $\left(1-m_B^{Y-C}\right)t^2$ for the profit function. Therefore, the new profit functions are as follows:

$$\pi_R^{Y-C} = \left(p_A^{Y-C} - w_A^{Y-C}\right)q_A^{Y-C} + \left(p_B^{Y-C} - w_B^{Y-C} - kt\right)q_B^{Y-C} - m_B^{Y-C}t^2 \tag{6}$$

$$\pi_M^{Y-C} = w_A^{Y-C}q_A^{Y-C} + w_B^{Y-C}q_B^{Y-C} - \left(1-m_B^{Y-C}\right)t^2 \tag{7}$$

Moreover, we compare the profits of the retailer, manufacturer, and supply chain. We also draw the results from the information cost of a unit product according to the above analysis. These results are helpful in improving our understanding of the equilibrium strategy. The results are presented in Proposition 3.

Proposition 3 (comparison of the profits for the firms under a cost-sharing contract)**.**

(1) $\pi_R^Y < \pi_R^{Y-C}$; $\pi_M^Y > \pi_M^{Y-C}$; $\pi_{SC}^Y = \pi_{SC}^{Y-C}$; *and* $c_B^Y > c_B^{Y-C}$.

(2) $m_B^{Y-C} \in \left(0, 1 - \dfrac{1+t\sigma^2\left(1+\theta\sigma^2\right)}{8t^2\left(1+t\sigma^2\right)} - \dfrac{\left(1-k\right)^2}{8\left(1-\theta\right)\theta}\right)$.

Proposition 3 presents the optimal strategy for a cost-sharing contract. Specifically, the equilibrium strategy for supply chain members is strategy Y-C, which refers to information sharing through a cost-sharing contract despite the unfavorable profit to the manufacturer.

In this case, the manufacturer must pay the cost proportion $m_B^{Y-C} \in \left(0, 1 - \frac{1+t\sigma^2\left(1+\theta\sigma^2\right)}{8t^2\left(1+t\sigma^2\right)} - \frac{(1-k)^2}{8(1-\theta)\theta}\right)$. From the perspective of the unit product information cost, the manufacturer incurs the cost of supporting information sharing with the blockchain system. This strategy avoids the manufacturer's free-riding. Moreover, this strategy implies that the unit information cost is lower than that in the basic model. Therefore, although the manufacturer must pay the cost of capturing customer information, it also obtains market information sharing from the retailer and exceeds the cost expenditure. In other words, a contract is an effective scheme for the supply chain members. Moreover, it can provide management implications for determining a reasonable cost-payment scheme within the effective cost ratio (m_B^{Y-C}) for firms.

4.4.2. The Discount Coupons

Next, we discuss a new contract to obtain the new scheme for mass customization. Specifically, we design the discount coupon plan for the manufacturer to determine the optimal strategy. As the leader of the supply chain, the manufacturer expects to obtain benefits that will pay the cost of discount coupons to customers and the retailer. It indirectly participates in the construction of a retailer's blockchain system under mass customization, which increases its market advantage. In other words, discount coupons can capture information from consumers and retailers to support the accuracy of their product plans for customized products.

Based on the above, we add discount coupon value s to retailers and consumers by the manufacturer, respectively. The new model seeks to obtain the market information required by the manufacturer from the information of the terminal market and retailer in the case of mass customization; it can guide the manufacturer in making reasonable production plans, including consumer habits, consumption preferences, and consumption behaviors. Therefore, we change the utility and profit functions based on the basic model as follows:

$$U_A^{Y-S} = V - p_A^{Y-S} \tag{8}$$

$$U_B^{Y-S} = V - p_B^{Y-S} + t + s \tag{9}$$

$$\pi_M^{Y-S} = w_A^{Y-S} q_A^{Y-S} + \left(w_B^{Y-S} - 2s\right) q_B^{Y-S} \tag{10}$$

$$\pi_R^{Y-S} = \left(p_A^{Y-S} - w_A^{Y-S}\right) q_A^{Y-S} + \left(p_B^{Y-S} - w_B^{Y-S} - kt + s\right) q_B^{Y-S} \tag{11}$$

In the case of mass customization, the manufacturer must pay both types of channel costs to indirectly support the construction of a retailer-sharing system. Moreover, we only consider that the discount coupons of customers and retailers have the same value, mainly focusing on changes in the optimal strategy. By comparing the profits of all the parties in the new and basic models, we obtain the analytical results of Proposition 4.

Proposition 4 (comparison of firms' profits under discount coupons)**.** $\pi_R^Y < \pi_R^{Y-S}$; $\pi_M^Y < \pi_M^{Y-S}$; $\pi_{SC}^Y < \pi_{SC}^{Y-S}$; *and* $c_B^Y > c_B^{Y-S}$.

Proposition 4 compares the firms' profits under discount coupons. Specifically, the equilibrium strategy is Y-S, which is an effective way to introduce a new strategy. Consequently, the manufacturer should use discount coupons to increase consumer surplus and guide consumers toward using mass customization. In other words, this strategy indirectly increases benefits to consumers through mass customization. Moreover, this helps increase the retailer's profit. Combined with the information cost per unit of product, strategy Y-S can reduce the information cost. An increase in the quantity of products dilutes the input cost of technology sharing in mass customization. Therefore, from the management's perspective for firms, the manufacturer can adopt a special scheme of discount coupons to satisfy the requirement of mass customization, thereby increasing the benefit of participating firms.

4.4.3. The Discount of the Wholesale Price

Next, we consider the wholesale price discount. Specifically, we designed a cost parameter to describe the change in wholesale prices in the new strategy. Firms use discount prices to obtain market resources such as enterprise relationship management. Thus, the firm incurs a relatively low price to retain business relationships. In other words, this strategy is called discount behavior. It has some discount types, such as wholesale and retail prices. We discuss the discount in wholesale prices for manufacturers, which can increase the product quantity for mass customization. In addition, the manufacturer attempts to indirectly reduce the wholesale price to obtain better results for mass customization under information sharing.

Based on the above-mentioned factors, we adopt the parameter of wholesale price in mass customization to capture the change in the wholesale price. Specifically, we add the parameter of the wholesale price ϕ into the basic model, resulting in the wholesale price being ϕw_B^{Y-D}. Moreover, by rewriting the profit function of the retailer and combining the exiting model design, the result of the new strategy Y-D can be obtained, which is shown as follows:

$$\pi_R^{Y-D} = \left(p_A^{Y-D} - w_A^{Y-D}\right) q_A^{Y-S} + \left(p_B^{Y-D} - \phi w_B^{Y-D} - kt\right) q_B^{Y-D} \tag{12}$$

Furthermore, we compare the profit of firms and information costs in the new and basic models, which provides the result in Proposition 5 and Figure 1. This result reveals the equilibrium strategy of firms, and provides a reference for the decision making of firms.

Proposition 5 (comparison of the profit for firms under the condition of wholesale price discount)**.** $\pi_R^{Y} > (<) \pi_R^{Y-D}$; $\pi_M^{Y} > (<) \pi_M^{Y-D}$; $\pi_{SC}^{Y} > (<) \pi_{SC}^{Y-D}$; $c_B^{Y} > (<) c_B^{Y-D}$.

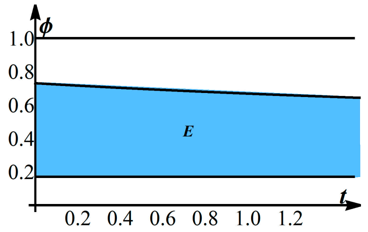

Figure 1. The result of equilibrium (E) ($k = 1$, $\theta = 1/2$, $\sigma = 1/2$).

Proposition 5 and Figure 1 show the equilibrium results between the basic and new models. Specifically, Proposition 5 compares firm profits under the condition of a wholesale price discount. These results indicate different cases. To show the result clearly, we have further drawn the results graph so that the changes in the equilibrium results can be visually displayed in Figure 1. This figure shows the results for equilibrium E. This shows that firms can reach an equilibrium when the discount factor must be maintained in the middle and low ranges. Moreover, this change indicates that discount factor ϕ must maintain a specific range to achieve equilibrium. The discount factor is further discussed, which shows that the discount factor designed by the manufacturer is not a bottomless change to balance the relationship between maintaining one's own profits and maintaining a going concern.

Additionally, the higher the accuracy of the retailer's blockchain system, the more attractive the discount ratio required by the manufacturer to achieve an equilibrium strategy under extreme conditions. Therefore, from the management perspective, the manufacturer can adopt a reasonable discount wholesale price to satisfy the requirement of mass customization, thus increasing the benefit of participating firms.

In summary, this study discusses the basic model and three types of contract designs to satisfy the requirement of an equilibrium strategy, including a cost-sharing contract, discount coupons, and discount on the wholesale price. Moreover, we provide management implications to support firms' decision making in the business activity process. To further explore additional schemes to support the optimal strategy, this study also analyzed the new results under different conditions.

5. Extensions

We further discuss the new conditions for finding a new equilibrium which can provide some new management implications: unreal product quantity in information sharing, the changes in the utility function for the basic analysis, the optimal strategy in the case of an uncovered market, the optimal strategy in the case of a product with a delay strategy, and the optimal strategy in the case of additional new technology.

5.1. The Case of Unreal Product Quantity in Information Sharing

Here, we consider the value of information sharing. Specifically, we design the case of unreal product quantity in information sharing owing to commercial factors. For example, a retailer wishes to obtain more products and profit in an environment of mass customization that may require more product quantity higher than the actual quantity. The manufacturer cannot control the business strategy because of the independent business relationship between the manufacturer and retailer.

Therefore, we design a new model to describe the changes in product quantity using y^{Y-R}. This parameter describes the proportion of quantity that may increase and is shown as $\left(1+y^{Y-R}\right)q_B^{Y-R}$ in the new product quantity. Based on this new quantity, we can change the profit functions of the manufacturer and retailer as follows:

$$\pi_M^{Y-R} = w_A^{Y-R}q_A^{Y-R} + \left(1+y^{Y-R}\right)w_B^{Y-R}q_B^{Y-R} \tag{13}$$

$$\pi_R^{Y-R} = \left(p_A^{Y-R} - w_A^{Y-R}\right)q_A^{Y-R} + \left(p_B^{Y-R} - w_B^{Y-R} - kt\right)q_B^{Y-R} \tag{14}$$

This is called strategy Y-R. Moreover, we compare the new strategy with the basic strategy to obtain the firms' equilibrium. In addition, we seek the relationship between the parameters of untrue product quantity ($\left(y_{MAX}^{Y-R}\right)^*$) and accuracy ($t$) of the supply chain system. Propositions 6 and Figure 2 present the results.

Proposition 6 (false quantity of products in the information-sharing environment).

(1) $\pi_R^Y > (<) \pi_R^{Y-R}$; $\pi_M^Y > (<) \pi_M^{Y-R}$; $\pi_{SC}^Y > (<) \pi_{SC}^{Y-R}$; *and* $c_B^Y > (<) c_B^{Y-R}$.

(2) *An optimal increment of false output* $\left(y_{MAX}^{Y-R}\right)^*$ *exists such that* $\frac{\partial\left(y_{MAX}^{Y-R}\right)^*}{\partial t} < 0$ *is satisfied when information is shared.*

Proposition 6 presents two aspects of this discussion. Specifically, Proposition 6 (1) shows the analytical results for firm profits. This result is consistent with the basic discussion. To clearly show the equilibrium result, we further visualize the results, as shown in Figure 2.

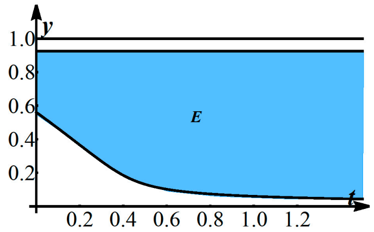

Figure 2. The result of equilibrium (E) ($k = 1/2$, $\theta = 9/10$, $\sigma = 1/2$).

Figure 2 shows the result of the equilibrium as E, in which the system accuracy changes (t) and the product quantity changes falsely (y^{Y-R}). This can be explained by the fact that y^{Y-R} has both upper and lower boundaries. In other words, although profit is high, the product quantity that the retailer can obtain is not limited to mass customization.

Furthermore, to reduce the influence of the optimal increment of false output $\left(y_{MAX}^{Y-R}\right)^*$, we seek the relationship between $\left(y_{MAX}^{Y-R}\right)^*$ and system accuracy (t). Proposition 6 (2) shows the relationship changes for both factors. It can be found that the higher the accuracy (t) of the blockchain system, the lower the proportion the optimal unreal product quantity ($\left(y_{MAX}^{Y-R}\right)^*$) will be. In other words, the blockchain system helps improve the distortion of market quantity, which also improves the technical value of commercial activity. Thus, the management implications can be derived. On the one hand, firms can use the unreal quantity of products to realize a new equilibrium strategy, which is helpful in increasing the firm's profit. In other words, the blockchain system in the supply chain can play the role of reducing unreasonable quantities, which reflects the technical value of resisting unreal market demand.

5.2. The Changes of Utility Function for Basic Analysis

In this section, we discuss the result of utility function changes. To be specific, we analyze the new strategy as X' ($X' = \pi_j^{i'}, i = M, R, SC; j = N, Y$). In the basic model, the utility function as $U_A > U_B > 0$ changes to the new utility function as $U_B > U_A > 0$ to obtain the new equilibrium strategy. The purpose of this model is to check the stability of the basic result. The profit functions are the same as the basic model. In other words, it takes into account the influence of the demand function changes caused by the change in utility function on the strategy result. Note that the utility of mass customization is higher than standard production product, which captures the potential changes in reality. Therefore, we analyze new conditions of the model to show the stability of the result, as shown in Proposition 7.

Proposition 7 (the stability of the result owing to the change in the utility of the function)**.**
$\pi_R^{N'} > \pi_R^{Y'}; \pi_M^{N'} < \pi_M^{Y'}; \ \pi_{SC}^{N'} > \pi_{SC}^{Y'}$.

Proposition 7 indicates that the result is a profit analysis after the utility function is changed. Specifically, this result is similar to that of the basic model and points to the manufacturer's sharing preferences. Moreover, this result is stable and shows the same effect on information-sharing preferences. The management implications are as follows: Although the structure of market demand has changed, retailers have not changed their existing manufacturer choices. Therefore, the manufacturer must consider new contracts such as cost-sharing contracts to achieve the equilibrium strategy.

5.3. The Optimal Strategy in the Case of an Uncovering Market

In this section, we expand the existing discussion to find new results for information sharing among firms. Specifically, in the basic analysis, we designed a complete market at the firm scale. In this subsection, we discuss the optimal strategy for an uncovered market. In reality, some firms have a part of the market scope for complex reasons, such as the influence of COVID-19. These reasons may lead to the shortening of the supply chain and make the market smaller, thus opening up all markets for enterprises.

In order to capture these changes in the market, we call this strategy Y-N. Specifically, the model is adopted as the distance cost of the consumer as x and cost parameter as ρ, which depicts the cost that consumers need to pay. Moreover, the market capacities of the standard product and mass customization are M. Accordingly, these market capacities are matched with the parameters of two market shares as λ_A^{Y-N} and λ_B^{Y-N}, respectively. In addition, we also provide the parameter l to capture the influence of system accuracy in the uncovered market. Furthermore, in order to find the optimal strategy, we design the cost transfer value F from manufacturer to retailer due to information sharing by the blockchain system of the retailer, which is called the strategy Y-N-C. In addition, we also analyze the firms' alliance, which is called strategy Y-N-CO. Therefore, we sort the new model settings which are shown as follows. The analytical result is shown as Proposition 8.

$$U_A^{N-C} = V - p_A - \rho x \tag{15}$$

$$U_B^{N-C} = \theta V - p_B - \rho x + lt \tag{16}$$

$$\pi_R^{Y-N} = \left(p_A^{Y-N} - w_A^{Y-N}\right)\lambda_A^{Y-N}M + \left(p_B^{Y-N} - w_B^{Y-N} - kt\right)\lambda_B^{Y-N}M - t^2 \tag{17}$$

$$\pi_M^{Y-N} = w_A^{Y-N}\lambda_A^{Y-N}M + w_B^{Y-N}\lambda_B^{Y-N}M \tag{18}$$

$$\pi_R^{Y-N-C} = \left(p_A^{Y-N} - w_A^{Y-N}\right)\lambda_A^{Y-N}M + \left(p_B^{Y-N} - w_B^{Y-N} - kt\right)\lambda_B^{Y-N}M - t^2 + F \tag{19}$$

$$\pi_M^{Y-N-C} = w_A^{Y-N}\lambda_A^{Y-N}M + w_B^{Y-N}\lambda_B^{Y-N}M - F \tag{20}$$

Proposition 8 (optimal strategy of incompletely covering the market)**.** $\pi_R^{Y-N} < \pi_R^{Y-N-C}$*;* $\pi_M^{Y-N} > \pi_M^{Y-N-C}$*;* $\pi_{SC}^{Y-N} = \pi_{SC}^{Y-N-C}$*; and* $\pi_R^{Y-N} < \pi_R^{Y-N-CO}$*.*

Proposition 8 shows two types of optimal strategies that do not completely cover the market. Specifically, on the one hand, the retailer's cost-sharing plan helps to increase the profit. Although the manufacturer needs to pay cost F, it can obtain the benefit of sharing information, which is called an effective scheme. This is because the manufacturer obtains superior information, but this advantage does not result in actual profit. Therefore, they choose a strategy that is different from that of the retailer. However, the adoption of strategic alliances can also help narrow the profit gap, which is a feasible choice for firms. Based on the above, management implications were obtained. First, a firm can use shared information by adding it into the manufacturer's fixed costs, which is the best choice for both parties. Firms can also use strategic alliances to achieve market superiority when uncovering a market.

5.4. The Optimal Strategy in the Case of a Product with a Delay Strategy

In this subsection, we present a new strategy for mass customization. Specifically, we use a delay strategy to achieve equilibrium. In fact, the delay strategy in mass customization can reduce the impact of the price increase in customized products, thereby increasing the product quantity in the market. In other words, this strategy produces a promotional effect at a relatively low price, which is more common for products with high price sensitivity.

Therefore, in mass customization, we adopt the delay parameter δ to describe the price changes in the delay-state environment. This delay strategy is known as the Y-DE strategy. In this model, we change the utility function based on the basis model to $U_B^{Y-DE} = \theta V - \delta p_B^{Y-S} + t$. Moreover, this study discusses two cases of the utility function: $U_A^{Y-DE} > U_B^{Y-DE}$ and $U_A^{Y-DE} < U_B^{Y-DE}$. By analyzing these two types of models, we show the optimal delay strategy in Propositions 9 and Figure 3.

Proposition 9 (optimal strategy of delay strategy)**.**

(1) *When* $U_A^{Y-DE} > U_B^{Y-DE}$ *and* $\frac{2-\theta-2\sqrt{1-\theta}}{\theta} < \delta < 1$: $\pi_R^Y < \pi_R^{Y-DE}$; $\pi_M^Y < \pi_M^{Y-DE}$; $\pi_{SC}^Y < \pi_{SC}^{Y-DE}$.

(2) *When* $U_A^{Y-DE} < U_B^{Y-DE}$: $\pi_R^Y > (<) \pi_R^{Y-DE}$; $\pi_M^Y > (<) \pi_M^{Y-DE}$; $\pi_{SC}^Y > (<) \pi_{SC}^{Y-DE}$.

Proposition 9 shows the optimal delay strategy for firms. Specifically, this strategy shows two cases of utility change. In the case of $U_A^{Y-DE} > U_B^{Y-DE}$, the equilibrium strategy is Y-DE when the $\frac{2-\theta-2\sqrt{1-\theta}}{\theta} < \delta < 1$. This means that the delay strategy is effective but cannot be too long, which needs to meet the requirements of the firms' profits. Moreover, in the case of $U_A^{Y-DE} < U_B^{Y-DE}$, the firms' equilibrium strategy is E. To show the results clearly, we have used Figure 3.

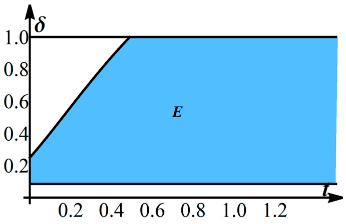

Figure 3. The result of equilibrium (E) ($k = 1/2$, $\theta = 1/2$, $\sigma = 1/2$).

The results in Figure 3 show that system accuracy helps improve the selection possibility of equilibrium results and reduces the impact of delayed activity. In other words, the delay strategy increases firms' profits. Therefore, the meaning of the management is obtained. For the mass customization of firms, they choose a reasonable delay time and method to help improve the profit of firms and benefit customers to activate the market.

5.5. The Optimal Strategy in the Case of Additional New Technology

Finally, we examine the influence of the adoption of big data technology. Specifically, we use a blockchain system to ensure information security during the information release process. Moreover, big data technology in an information system can capture large amounts of business information. In other words, both technologies can achieve secure information sharing. In reality, Walmart uses blockchain in combination with big data analytics to enhance transparency and traceability in its supply chain. By integrating blockchain with real-time data from IoT sensors, Walmart tracks the origin and journey of food products, ensuring safety and reducing spoilage. Big data analytics helps in predicting trends and optimizing inventory management.

Specifically, we adopt big data technology for the retailer because it is close to the end market. The cost of big data technology is c per product of mass customization. Moreover, to achieve a high level of information sharing, the manufacturer provides a fixed-cost F to the retailer. Finally, customers can benefit from two technologies—the blockchain system and big data—which show changes in the utility function. To capture the technology benefit-to-cost ratio (BCB) in big data, we adopted $BCB = b / c$ to demonstrate the value of big data technology. $BCB > 1$, $BCB = 1$, and $BCB < 1$ represent beneficial, neutral, and harmful effects, respectively [47]. Correspondingly, this new strategy is referred to as Y-NEW. The new utility and profit functions are as follows: Proposition 10 presents these results.

$$U_A^{Y-NEW} = V - p_A^{Y-NEW} \tag{21}$$

$$U_B^{Y-NEW} = \theta V - p_B^{Y-NEW} + t + b \tag{22}$$

$$\pi_R^{Y-NEW} = \left(p_A^{Y-NEW} - w_A^{Y-NEW}\right)q_A^{Y-NEW} + \left(p_B^{Y-NEW} - w_B^{Y-NEW} - kt - c\right)q_B^{Y-NEW} - t^2 + F \tag{23}$$

$$\pi_M^{Y-NEW} = w_A^{Y-NEW} q_A^{Y-NEW} + w_B^{Y-NEW} q_B^{Y-NEW} - F \tag{24}$$

Proposition 10 (the optimal strategy of new technology enhancement)**.**

(1) *When* $BCB > 1$ *and* $0 < F < \frac{\left((b-c)+2t(1-k)\right)(b-c)}{8\theta(1-\theta)}$: $\pi_R^Y < \pi_R^{Y-NEW}$; $\pi_M^Y < \pi_M^{Y-NEW}$; $\pi_{SC}^Y < \pi_{SC}^{Y-NEW}$.

(2) *When* $BCB \le 1$, $0 < t < \frac{c-b}{2(1-k)}$, *and* $0 < F < \frac{\left((b-c)+2t(1-k)\right)(b-c)}{8\theta(1-\theta)}$: $\pi_R^Y < \pi_R^{Y-NEW}$; $\pi_M^Y < \pi_M^{Y-NEW}$; $\pi_{SC}^Y < \pi_{SC}^{Y-NEW}$.

Proposition 10 presents the optimal strategy for enhancing the new technology. Specifically, on the one hand, when the technology is beneficial ($BCB > 1$), as long as the investment cost of technical compensation does not exceed the specific range ($0 < F < \frac{\left((b-c)+2t(1-k)\right)(b-c)}{8\theta(1-\theta)}$), the strategy of technology enhancement can reach equilibrium. This result is helpful in realizing the Y-NEW equilibrium strategy. However, when technology is harmful ($BCB \le 1$), the equilibrium strategy conditions are $0 < F < \frac{\left((b-c)+2t(1-k)\right)(b-c)}{8\theta(1-\theta)}$ and $0 < t < \frac{c-b}{2(1-k)}$. In this case, the equilibrium strategy is Y-NEW. These results are common in the Y-NEW equilibrium strategy. In other words, big data is effective as an enhanced sharing technology, particularly when the accuracy of blockchain technology is not high. Big data can provide full play to its technological advantages. Management implications are obtained based on the results of the discussion. A firm can consider adopting a variety of technologies to gain market superiority, especially in a mass-customized environment. In other words, a variety of technologies can quickly capture consumers' habits and behaviors and realize the technical value of sharing relevant data with firms.

6. Discussion

This study discusses strategies based on changes in contracts to seek the optimal strategy. Therefore, for a deeper discussion, we sort the strategies to show the potential development laws. Specifically, in the basic model, an optimal strategy for the manufacturer and retailer does not exist. In other words, although the manufacturer prefers to obtain information from the retailer through the blockchain system, the retailer cannot share the information because of construction cost limitations. Furthermore, to find a reasonable solution, we discuss some new types of contracts to obtain the equilibrium strategy, including the cost-sharing contract, discount coupons, wholesale price discounts, unreal product quantity in information sharing, the optimal strategy in the case of an uncovered market, optimal strategy in the case of a product with a delay strategy, and the optimal strategy in the case of additional new technology. Specifically, these contracts under different conditions find the optimal strategy that guides the information benefit of the manufacturer from the retailer in mass customization. Among them, the basic idea is that the cost of obtaining information for the manufacturer should be similar to the cost of technical investment. In other words, the firm expects to obtain benefits from information sharing and must pay the cost as well.

7. Conclusions, Managerial Implications, and Limitations

7.1. Conclusions

We develop game-theoretical models involving manufacturers and retailers to explore the retailer's optimal information-sharing strategy in a mass customization environment. Specifically, we focus on the retailer's ability to share terminal market information about nearby consumers, which is essential for mass customization. This analysis helps to clarify the manufacturer's incentives to support the retailer in establishing blockchain systems for two types of products: standard and customized products. Our investigation reveals the following preliminary conclusions:

First, retailers cannot share market information without incurring costs to manufacturers, meaning that no information can be exchanged "early" without some form of compensation. Second, by coordinating cost-sharing contracts, discount coupons, and wholesale price discounts, the manufacturer and retailer can achieve an equilibrium strategy under specific conditions. Lastly, the results hold even when the underlying assumptions are adjusted, such as altering the utility function or finding new market conditions. We also identify new equilibrium strategies under various scenarios, including handling unreal product quantities in information sharing, optimizing strategies for products with delayed delivery policies, and strategies for incorporating new technologies.

7.2. Managerial Implications

From the manufacturer's perspective, it is crucial to consider the market conditions in a mass customization environment when evaluating the retailer's information-sharing strategy. Manufacturers should implement blockchain systems to facilitate secure information sharing with retailers, leveraging the technology's ability to prevent data tampering. Moreover, manufacturers should adopt optimal strategies under well-structured contract conditions, such as cost-sharing contracts, discount coupons, wholesale price discounts, unreal product quantities in information sharing, strategies for uncovered markets, delayed product strategies, and incorporating new technologies. These contract mechanisms are vital for ensuring the quality and reliability of information shared by the retailer.

From the retailer's perspective, implementing a blockchain system can protect the integrity of data within the supply chain, ensuring that relevant data are not tampered with. Retailers should evaluate optimal strategies for sharing information with the manufacturer to enhance the benefits derived from data sharing. Additionally, retailers can leverage big data technologies in conjunction with blockchain to maximize technical value, creating a more efficient and transparent information-sharing ecosystem. Together, these technologies can significantly improve the retailer's operational capabilities and overall business strategy.

7.3. Limitations and Future Work

First, we use information sharing to improve the market value of mass customization. Future research should consider the competitive environment of mass customization. Second, the government should also be considered in the model. We did not consider the government's role in smart sales, especially the power of technology, such as oversight or technological subsidies. Future research could explore competitive dynamics in mass customization markets, incorporate government roles like subsidies or oversight. Moreover, it also could analyze consumer behavior's impact on information sharing. Additionally, investigating the integration of emerging technologies and their ethical implications could provide further insights.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Basic Results

1. The supply chain does not use the solution of information sharing (N):

$$p_A^N = \frac{3}{4} + \frac{t\Gamma\theta\sigma^2}{2+2t\sigma^2}$$

$$p_B^N = \frac{1}{4}\left(3\theta + t\left(3 + k + \frac{2\Gamma\theta\sigma^2}{1+t\sigma^2}\right)\right)$$

$$q_A^N = \frac{1-\theta-(1-k)t}{4(1-\theta)}$$

$$q_B^N = \frac{1}{4}\left(\frac{(1-k)t}{(1-\theta)\theta} + \frac{2t\Gamma\sigma^2}{1+t\sigma^2}\right)$$

$$w_A^N = \frac{1}{2}$$

$$w_B^N = \frac{(1-k)t+\theta}{2}$$

$$\pi_R^N = \frac{1}{16}\left(1 + \frac{t^2\left(1-(2-k)k-16(1-\theta)\theta\right)}{(1-\theta)\theta} + \frac{4t\theta\sigma^4}{1+t\sigma^2}\right)$$

$$\pi_M^N = \frac{1}{8}\left(1 + \frac{(1-k)^2 t^2}{(1-\theta)\theta}\right)$$

$$\pi_{SC}^N = \frac{1}{16}\left(3 + \frac{t^2\left(3(1-k)^2-16(1-\theta)\theta\right)}{(1-\theta)\theta} + \frac{4t\theta\sigma^4}{1+t\sigma^2}\right)$$

2. The supply chain uses the solution of information sharing (Y):

$$p_A^Y = \frac{3}{4}\left(1 + \frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$p_B^Y = \frac{1}{4}\left(3\theta + t\left(3 + k + \frac{3\Gamma\theta\sigma^2}{1+t\sigma^2}\right)\right)$$

$$q_A^Y = \frac{1-\theta-(1-k)t}{4(1-\theta)}$$

$$q_B^Y = \frac{1}{4}\left(\frac{(1-k)t}{(1-\theta)\theta} + \frac{t\Gamma\sigma^2}{1+t\sigma^2}\right)$$

$$w_A^Y = \frac{1}{2}\left(1 + \frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$w_B^Y = \frac{1}{2}\left((1-k)t + \theta + \frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$\pi_R^Y = \frac{1}{16}\left(1 + \frac{t^2\left(1-(2-k)k-16(1-\theta)\theta\right)}{(1-\theta)\theta} + \frac{t\theta\sigma^4}{1+t\sigma^2}\right)$$

$$\pi_M^Y = \frac{1}{8}\left(1 + \frac{(1-k)^2 t^2}{(1-\theta)\theta} + \frac{t\theta\sigma^4}{1+t\sigma^2}\right)$$

$$\pi_{SC}^Y = \frac{1}{16}\left(3 + \frac{t^2\left(3(1-k)^2-16(1-\theta)\theta\right)}{(1-\theta)\theta} + \frac{3t\theta\sigma^4}{1+t\sigma^2}\right)$$

3. The supply chain uses the solution of information sharing in the case of cost-sharing (Y-C):

$$p_A^{Y-C} = \frac{3}{4}\left(1 + \frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$p_B^{Y-C}=\frac{1}{4}\left(3\theta+t\left(3+k+\frac{3\Gamma\theta\sigma^2}{1+t\sigma^2}\right)\right)$$

$$q_A^{Y-C}=\frac{1-\theta-(1-k)t}{4(1-\theta)}$$

$$q_B^{Y-C}=\frac{1}{4}\left(\frac{(1-k)t}{(1-\theta)\theta}+\frac{t\Gamma\sigma^2}{1+t\sigma^2}\right)$$

$$w_A^{Y-C}=\frac{1}{2}\left(1+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$w_B^{Y-C}=\frac{1}{2}\left((1-k)t+\theta+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$\pi_R^{Y-C}=\frac{1}{16}\left(1-16m_B^{Y-C}t^2-\frac{(-1+k)^2t^2}{(-1+\theta)\theta}+\frac{t\theta\sigma^4}{1+t\sigma^2}\right)$$

$$\pi_M^{Y-C}=\frac{1}{8}\left(1+\frac{t^2\left(1-(2-k)k-8\theta\left(1-m_B^{Y-C}\right)(1-\theta)\right)}{(1-\theta)\theta}+\frac{t\theta\sigma^4}{1+t\sigma^2}\right)$$

$$\pi_{SC}^{Y-C}=\frac{1}{16}\left(3+\frac{t^2\left(3(1-k)^2-16(1-\theta)\theta\right)}{(1-\theta)\theta}+\frac{3t\theta\sigma^4}{1+t\sigma^2}\right)$$

4. The supply chain uses the solution of information sharing in the case of discount coupons (Y-S):

$$p_A^{Y-S}=\frac{3}{4}\left(1-s+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$p_B^{Y-S}=\frac{1}{4}\left(3\theta+s+t\left(3+k+\frac{3\Gamma\theta\sigma^2}{1+t\sigma^2}\right)\right)$$

$$q_A^{Y-S}=\frac{1-\theta-(1-k)t}{4(1-\theta)}$$

$$q_B^{Y-S}=\frac{(1-k)t-(1-\theta)s}{4(1-\theta)\theta}+\frac{t\Gamma\sigma^2}{4\left(1+t\sigma^2\right)}$$

$$w_A^{Y-S}=\frac{1}{2}\left(1-s+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$w_B^{Y-S}=\frac{1}{2}\left((1-k)t+3s+\theta+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$\pi_R^{Y-S}=\frac{1-16t^2\left(1+t\sigma^2\right)}{16\left(1+t\sigma^2\right)}+\frac{(1-k)^2t^2}{16(1-\theta)\theta}+\frac{s^2-2s\left((1-k)t+\theta\right)}{16\theta}+\frac{t\sigma^2(1-\theta)\left(1+\sigma^2\theta\right)}{16(1+\theta)\left(1+t\sigma^2\right)}$$

$$\pi_M^{Y-S}=\frac{1+t\sigma^2\left(1+\theta\sigma^2\right)}{8\left(1+t\sigma^2\right)}+\frac{(1-k)^2t^2}{8(1-\theta)\theta}+\frac{s^2-2s\left((1-k)t+\theta\right)}{8\theta}$$

$$\pi_{SC}^{Y-S}=\frac{3\left(1+t\sigma^2\left(1+\theta\sigma^2\right)\right)}{16\left(1+t\sigma^2\right)}+\frac{3(1-k)^2t^2}{16(1-\theta)\theta}+\frac{3s^2-6s\left((1-k)t+\theta\right)}{16\theta}-t^2$$

5. The supply chain uses the solution of information sharing in the case of discount of wholesale price (Y-D):

$$p_A^{Y-D}=\frac{1}{2}\left(1+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}+\frac{t(1-k)(1-\phi)}{4\phi-\theta(1+\phi)^2}+\frac{(1-\theta)}{4\phi-\theta(1+\phi)^2}\left(2\phi+\frac{t\Gamma\theta\sigma^2(1+\phi)}{1+t\sigma^2}\right)\right)$$

$$p_B^{Y-D}=\frac{1}{2}\left((1+k)t+\theta+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}+\frac{(1-k)\left(2-(1+\phi)\theta\right)t\phi}{4\phi-\theta(1+\phi)^2}+\frac{\phi(1-\theta)\theta}{4\phi-\theta(1+\phi)^2}\left(1+\frac{2t\Gamma\sigma^2}{1+t\sigma^2}+\phi\right)\right)$$

$$q_A^{Y-D}=\frac{2\phi-(1-k)(1+\phi)t}{2\left(4\phi-\theta(1+\phi)^2\right)}-\frac{\theta\left(1+\phi+t\sigma^2\left(1+\Gamma+(1-\Gamma)\phi\right)\right)}{2\left(1+t\sigma^2\right)\left(4\phi-\theta(1+\phi)^2\right)}$$

$$q_B^{Y-D}=\frac{(1-k)t\phi}{\theta\left(4\phi-\theta(1+\phi)^2\right)}+\frac{\phi(1-\phi)}{2\left(4\phi-\theta(1+\phi)^2\right)}+\frac{\phi\left(t\Gamma\sigma^2\left(2-\theta(1+\phi)\right)\right)}{2\left(1+t\sigma^2\right)\left(4\phi-\theta(1+\phi)^2\right)}$$

$$w_A^{Y-D}=\frac{t(1-k)(1-\phi)+2\phi(1-\theta)}{4\phi-\theta(1+\phi)^2}+\frac{t\Gamma\theta\sigma^2(1+\phi)(1-\theta)}{\left(1+t\sigma^2\right)\left(4\phi-\theta(1+\phi)^2\right)}$$

$$w_B^{Y-D}=\frac{(1-k)t\left(2-(1+\phi)\theta\right)+(1-\theta)\theta(1+\phi)}{4\phi-\theta(1+\phi)^2}+\frac{2t\Gamma\sigma^2(1-\theta)\theta}{\left(1+t\sigma^2\right)\left(4\phi-\theta(1+\phi)^2\right)}$$

$$\pi_R^{Y-D}=\frac{\left(\begin{array}{l}
\theta\left(\theta^2-\phi\left(\left(4\theta-\left(4+\theta+\theta^2\right)\phi\right)+\theta\phi^2\left(2(3-\theta)+\phi\right)\right)\right)+\\
t^3\sigma^2\left(4(1-k)^2\phi^2+\theta\left(4(1+\phi)^2\theta\left(8\phi-\theta(1+\phi)^2\right)+\left((1-k)^2(1-2\phi)-\left(67-3(2-k)k\right)\phi^2\right)\right)\right)+\\
+t^2\left(\begin{array}{l}
4(1-k)^2\phi^2-2\theta^2(1+\phi)\left(2\theta(1+\phi)^3+\left((1-k)(1-\phi)^2\sigma^2-16\phi(1+\phi)\right)\right)\\
+\theta\left(1+k^2(1+\phi)(1-3\phi)-\phi\left(2+4\sigma^2(1-\phi)^2+67\phi\right)-k\left(2-2\phi\left(2+2\sigma^2(1-\phi)^2+3\phi\right)\right)\right)
\end{array}\right)+\\
\left(t\theta\left(\begin{array}{l}
4\phi\left(k(1-\phi)^2-1+\left(2+\sigma^2-\phi\right)\phi\right)+\theta^3\sigma^4\phi\left(2+\phi\left(1+\phi^2\right)\right)+\\
\theta^2\sigma^2\left(1+(1+2\phi)\phi^2+\sigma^2\left(1-\phi\left(6-\phi(1-4\phi)\right)\right)\right)+\\
\theta\left(2-2k(1-\phi)^2(1+\phi)-2\phi\left(1-\phi\left(2\sigma^4-(1-\phi)\right)+\sigma^2\left(4-\phi+(6-\phi)\phi^2\right)\right)\right)
\end{array}\right)\right)
\end{array}\right)}{4\left(\theta+t\theta\sigma^2\right)\left(4\phi-\theta(1+\phi)^2\right)^2}$$

$$\pi_M^{Y-D}=\frac{(1-k)^2t^2+(1-k)t\theta-(1-k)t\theta\phi+(1-\theta)\theta\phi}{2\theta\left(4\phi-\theta(1+\phi)^2\right)}+\frac{t(1-\theta)\theta^2\sigma^4}{2\theta\left(1+t\sigma^2\right)\left(4\phi-\theta(1+\phi)^2\right)}$$

$$\pi_{SC}^{Y-D}=\frac{\left(\begin{array}{l}\theta\left(\theta^2-\phi\left(\left(4\theta-\left(4+\theta+\theta^2\right)\phi\right)+\theta\phi^2\left(2(3-\theta)+\phi\right)\right)\right)+\\ t^3\sigma^2\left(4(1-k)^2\phi^2+\theta\left(4(1+\phi)^2\theta\left(8\phi-\theta(1+\phi)^2\right)+\left((1-k)^2(1-2\phi)-\left(67-3(2-k)k\right)\phi^2\right)\right)\right)+\\ +t^2\left(\begin{array}{l}4(1-k)^2\phi^2-2\theta^2(1+\phi)\left(2\theta(1+\phi)^3+\left((1-k)(1-\phi)^2\sigma^2-16\phi(1+\phi)\right)\right)\\ +\theta\left(1+k^2(1+\phi)(1-3\phi)-\phi\left(2+4\sigma^2(1-\phi)^2+67\phi\right)-k\left(2-2\phi\left(2+2\sigma^2(1-\phi)^2+3\phi\right)\right)\right)\end{array}\right)+\\ \left(t\theta\left(\begin{array}{l}4\phi\left(k(1-\phi)^2-1+\left(2+\sigma^2-\phi\right)\phi\right)+\theta^3\sigma^4\phi\left(2+\phi\left(1+\phi^2\right)\right)+\\ \theta^2\sigma^2\left(1+(1+2\phi)\phi^2+\sigma^2\left(1-\phi\left(6-\phi(1-4\phi)\right)\right)\right)+\\ \theta\left(2-2k(1-\phi)^2(1+\phi)-2\phi\left(1-\phi\left(2\sigma^4-(1-\phi)\right)+\sigma^2\left(4-\phi+(6-\phi)\phi^2\right)\right)\right)\end{array}\right)\right)\end{array}\right)}{4\left(\theta+t\theta\sigma^2\right)\left(4\phi-\theta(1+\phi)^2\right)^2}+$$
$$\frac{(1-k)^2t^2+(1-k)t\theta-(1-k)t\theta\phi+(1-\theta)\theta\phi}{2\theta\left(4\phi-\theta(1+\phi)^2\right)}+\frac{t(1-\theta)\theta^2\sigma^4}{2\theta\left(1+t\sigma^2\right)\left(4\phi-\theta(1+\phi)^2\right)}$$

6. The supply chain uses the solution of information sharing in the case of unreal product quantity (Y-R):

$$p_A^{Y-R}=\frac{1}{2}\left(1+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}+\frac{(1+y)}{4(1+y)-(2+y)^2\theta}\left((1-k)ty+(1-\theta)\left(2+\frac{t(2+y)\Gamma\theta\sigma^2}{1+t\sigma^2}\right)\right)\right)$$

$$p_B^{Y-R}=\frac{1}{2}\left(\begin{array}{l}t+kt+\theta+\dfrac{t\Gamma\theta\sigma^2}{1+t\sigma^2}+\dfrac{\left((1-k)t\left(2(1+y)-(2+y)\theta\right)\right)}{4(1+y)-(2+y)^2\theta}-\\ \dfrac{(1-\theta)\theta}{4(1+y)-(2+y)^2\theta}\left(2+y+\dfrac{2t(1+y)\Gamma\sigma^2}{1+t\sigma^2}\right)\end{array}\right)$$

$$q_A^{Y-R}=\frac{(1+y)\left(2-(1-k)t(2+y)\right)}{8(1+y)-2(2+y)^2\theta}-\frac{(1+y)\theta}{8(1+y)-2(2+y)^2\theta}\left(2+y+\frac{ty\Gamma\sigma^2}{1+t\sigma^2}\right)$$

$$q_B^{Y-R}=\frac{2(1-k)t(1+y)}{2\theta\left(4(1+y)-(2+y)^2\theta\right)}+\frac{y\theta+t\left(y\left(1+\Gamma(2-\theta)\right)+2\Gamma(1-\theta)\right)\theta\sigma^2}{2\theta\left(4(1+y)-(2+y)^2\theta\right)\left(1+t\sigma^2\right)}$$

$$w_A^{Y-R}=\frac{(1+y)\left((1-k)ty\right)}{4(1+y)-(2+y)^2\theta}+\frac{(1+y)(1-\theta)}{4(1+y)-(2+y)^2\theta}\left(2+\frac{t(2+y)\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$w_B^{Y-R}=\frac{(1-k)t\left(2(1+y)-(2+y)\theta\right)}{4(1+y)-(2+y)^2\theta}+\frac{(1-\theta)\theta}{4(1+y)-(2+y)^2\theta}\left(2+y+\frac{2t(1+y)\Gamma\sigma^2}{1+t\sigma^2}\right)$$

$$\pi_R^{Y-R}=\frac{1}{4}\left(\begin{array}{l}-4t^2+\dfrac{(1+y)(2-(1-k)t(2+y)-(2+y)\theta)((1+y)(2-(1-k)ty)-(2+y(2+y))\theta)}{\left(4(1+y)-(2+y)^2\theta\right)^2}+\\ \dfrac{(2(1-k)t(1+y)+y\theta)(((1-k)t(1+y)(2-(2+y)\theta))-\theta(2+3y-(1+y)(2+y)\theta))}{\theta\left(4(1+y)-(2+y)^2\theta\right)^2}\end{array}\right)$$

$$\pi_M^{Y-R}=\frac{(1+y)\left((1-k)^2t^2(1+y)+(1-k)ty\theta+(1-\theta)\theta\right)}{2\theta\left(4(1+y)-(2+y)^2\theta\right)}$$

$$\pi_{SC}^{Y-R}=\frac{1}{4}\left(\begin{array}{l}-4t^2+\dfrac{(1+y)(2-(1-k)t(2+y)-(2+y)\theta)((1+y)(2-(1-k)ty)-(2+y(2+y))\theta)}{\left(4(1+y)-(2+y)^2\theta\right)^2}+\\ \dfrac{(2(1-k)t(1+y)+y\theta)(((1-k)t(1+y)(2-(2+y)\theta))-\theta(2+3y-(1+y)(2+y)\theta))}{\theta\left(4(1+y)-(2+y)^2\theta\right)^2}\end{array}\right)+\frac{(1+y)\left((1-k)^2t^2(1+y)+(1-k)ty\theta+(1-\theta)\theta\right)}{2\theta\left(4(1+y)-(2+y)^2\theta\right)}$$

7. The new utility function in the case of non-sharing in the market information (N′):

$$p_A^{N'}=\frac{5-(1-k)t+\theta}{2(3+\theta)}+\frac{2t\Gamma(1+\theta)\sigma^2}{2(3+\theta)(1+t\sigma^2)}$$

$$p_B^{N'}=\frac{1+\theta(4+\theta)}{2(3+\theta)}+\frac{t(4+\theta+k(2+\theta))}{2(3+\theta)}+\frac{4\Gamma\sigma^2t}{2(3+\theta)(1+t\sigma^2)}$$

$$q_A^{N'}=\frac{1}{2(3+\theta)}\left(2+\theta+\frac{2t\Gamma\sigma^2}{1+t\sigma^2}\right)-\frac{(1-k)(1+\theta)t}{2(1-\theta)(3+\theta)}$$

$$q_B^{N'}=\frac{(1-k)t}{(1-\theta)(3+\theta)}-\frac{1}{2(3+\theta)}\left(1-\frac{2t\Gamma\sigma^2}{1+t\sigma^2}\right)$$

$$w_A^{N'}=\frac{1}{2}$$

$$w_B^{N'}=\frac{(1-k)t+\theta}{2}$$

$$\pi_R^{N'}=\frac{1-\theta-t^3(11+(2-k)k-4\theta(2+\theta))\sigma^2}{4(1-\theta)(3+\theta)(1+t\sigma^2)}-\frac{t^2(11+2k(1+2(2-\theta)\theta k)+(1-k)(1-\theta)\sigma^2)}{4(1-\theta)(3+\theta)(1+t\sigma^2)}-\frac{t(1-k-\sigma^2(1+4\sigma^2))}{4(3+\theta)(1+t\sigma^2)}$$

$$\pi_M^{N'}=\frac{1-(1-k)(1-(1-k)t-\theta)t-\theta}{2(1-\theta)(3+\theta)}$$

$$\pi_{SC}^{N'}=\frac{1-\theta-t^{3}\left(11+(2-k)k-4\theta(2+\theta)\right)\sigma^{2}}{4(1-\theta)(3+\theta)\left(1+t\sigma^{2}\right)}-\frac{t^{2}\left(11+2k\left(1+2(2-\theta)\theta k\right)+(1-k)(1-\theta)\sigma^{2}\right)}{4(1-\theta)(3+\theta)\left(1+t\sigma^{2}\right)}$$
$$-\frac{t\left(1-k-\sigma^{2}\left(1+4\sigma^{2}\right)\right)}{4(3+\theta)\left(1+t\sigma^{2}\right)}+\frac{1-(1-k)\left(1-(1-k)t-\theta\right)t-\theta}{2(1-\theta)(3+\theta)}$$

8. The new utility function in the case of sharing in the market information (Y′):

$$p_{A}^{Y'}=\frac{5+\theta-(1-k)t}{2(3+\theta)}+\frac{t\Gamma(2+\theta)\sigma^{2}}{(3+\theta)\left(1+t\sigma^{2}\right)}$$

$$p_{B}^{Y'}=\frac{1+\theta(4+\theta)+t\left(4+\theta+k(2+\theta)\right)}{2(3+\theta)}+\frac{t\Gamma(5+\theta)\sigma^{2}}{2(3+\theta)\left(1+t\sigma^{2}\right)}$$

$$q_{A}^{Y'}=\frac{1}{2(3+\theta)}\left(2+\Gamma+\theta-\frac{\Gamma}{1+t\sigma^{2}}\right)-\frac{(1-k)t(1+\theta)}{2(1-\theta)(3+\theta)}$$

$$q_{B}^{Y'}=\frac{2(1-k)t}{2(1-\theta)(3+\theta)}-\frac{1}{2(3+\theta)}\left(1-\Gamma+\frac{\Gamma}{1+t\sigma^{2}}\right)$$

$$w_{A}^{Y'}=\frac{1}{2}\left(1+\Gamma-\frac{\Gamma}{1+t\sigma^{2}}\right)$$

$$w_{B}^{Y'}=\frac{1}{2}\left((1-k)t+\Gamma+\theta-\frac{\Gamma}{1+t\sigma^{2}}\right)$$

$$\pi_{R}^{Y'}=\frac{1-\theta-t^{3}\left(11+(2-k)k-4\theta(2+\theta)\right)\sigma^{2}}{4(1-\theta)(3+\theta)\left(1+t\sigma^{2}\right)}-\frac{t^{2}\left(11+k(2-k)-4\theta(2+\theta)+(1-k)(1-\theta)\sigma^{2}\right)}{4(1-\theta)(3+\theta)\left(1+t\sigma^{2}\right)}$$
$$-\frac{t\left(1-k-\sigma^{2}\left(1+\sigma^{2}\right)\right)}{4(3+\theta)\left(1+t\sigma^{2}\right)}$$

$$\pi_{M}^{Y'}=\frac{1-\theta+(1-k)^{2}t^{3}\sigma^{2}+(1-k)t^{2}\left(1-k-\sigma^{2}(1-\theta)\right)-t(1-\theta)\left(1-k+\sigma^{2}\left(1+\sigma^{2}\right)\right)}{2(1-\theta)(3+\theta)\left(1+t\sigma^{2}\right)}$$

$$\pi_{SC}^{Y'}=\frac{1-\theta-t^{3}\left(11+(2-k)k-4\theta(2+\theta)\right)\sigma^{2}}{4(1-\theta)(3+\theta)\left(1+t\sigma^{2}\right)}-\frac{t^{2}\left(11+k(2-k)-4\theta(2+\theta)+(1-k)(1-\theta)\sigma^{2}\right)}{4(1-\theta)(3+\theta)\left(1+t\sigma^{2}\right)}$$
$$-\frac{t\left(1-k-\sigma^{2}\left(1+\sigma^{2}\right)\right)}{4(3+\theta)\left(1+t\sigma^{2}\right)}+\frac{1-\theta+(1-k)^{2}t^{3}\sigma^{2}+(1-k)t^{2}\left(1-k-\sigma^{2}(1-\theta)\right)-t(1-\theta)\left(1-k+\sigma^{2}\left(1+\sigma^{2}\right)\right)}{2(1-\theta)(3+\theta)\left(1+t\sigma^{2}\right)}$$

9. The supply chain uses the solution of information sharing in the case of uncovering all the market share (Y-N):

$$p_{A}^{Y-N}=\frac{3V}{4}$$

$$p_{B}^{Y-N}=\frac{1}{4}\left(kt+3\left(lt+V\theta+\Gamma-\frac{\Gamma}{1+t\sigma^{2}}\right)\right)$$

$$\lambda_A^{Y-N} = \frac{V}{2\rho}$$

$$\lambda_B^{Y-N} = \frac{1}{2\rho}\left(V\theta + \Gamma - \frac{\Gamma}{1+t\sigma^2} - (k-l)t\right)$$

$$w_A^{Y-N} = \frac{V}{2}$$

$$w_B^{Y-N} = \frac{1}{2}\left(V\theta + \Gamma - \frac{\Gamma}{1+t\sigma^2} - (k-l)t\right)$$

$$\pi_R^{Y-N} = \frac{\left((k-l)^2 t^2 + V\left(V\left(1+\theta^2\right) - 2(k-l)t\theta\right)\right)M + t\left(M\left(V^2 + (-kt+lt+V\theta)^2\right) - 8t^2\rho\right)\sigma^2 + Mt\sigma^4 - 8t^2\rho}{8\left(\rho + t\rho\sigma^2\right)}$$

$$\pi_M^{Y-N} = \frac{M\left(V^2 + (kt-lt-V\theta)^2 + t\left(V^2 + (kt-lt-V\theta)^2\right)\sigma^2 + t\sigma^4\right)}{4\left(\rho + t\rho\sigma^2\right)}$$

$$\pi_{SC}^{Y-N} = \frac{\left((k-l)^2 t^2 + V\left(V\left(1+\theta^2\right) - 2(k-l)t\theta\right)\right)M + t\left(M\left(V^2 + (-kt+lt+V\theta)^2\right) - 8t^2\rho\right)\sigma^2 + Mt\sigma^4 - 8t^2\rho}{8\left(\rho + t\rho\sigma^2\right)}$$
$$+\frac{M\left(V^2 + (kt-lt-V\theta)^2 + t\left(V^2 + (kt-lt-V\theta)^2\right)\sigma^2 + t\sigma^4\right)}{4\left(\rho + t\rho\sigma^2\right)}$$

10. The supply chain uses the solution of information sharing in the case of uncovering all the market share and cost-sharing (Y-N-C):

$$\pi_R^{Y-N-C} = \frac{\left((k-l)^2 t^2 + V\left(V\left(1+\theta^2\right) - 2(k-l)t\theta\right)\right)M + t\left(M\left(V^2 + (-kt+lt+V\theta)^2\right) - 8t^2\rho\right)\sigma^2 + Mt\sigma^4 - 8t^2\rho}{8\left(\rho + t\rho\sigma^2\right)} + F$$

$$\pi_M^{Y-N-C} = \frac{M\left(V^2 + (kt-lt-V\theta)^2 + t\left(V^2 + (kt-lt-V\theta)^2\right)\sigma^2 + t\sigma^4\right)}{4\left(\rho + t\rho\sigma^2\right)} - F$$

11. The supply chain uses the solution of information sharing in the case of uncovering all the market share and alliance (Y-N-CO):

$$p_A^{Y\text{-}N\text{-}CO} = \frac{V}{2}$$

$$p_B^{Y\text{-}N\text{-}CO} = \frac{1}{2}\left((k+l)t + \Gamma + V\theta - \frac{\Gamma}{1+t\sigma^2}\right)$$

$$\lambda_A^{Y\text{-}N\text{-}CO} = \frac{V}{\rho}$$

$$\lambda_B^{Y-N} = \frac{V\theta + \Gamma - (k-l)t}{\rho} - \frac{\Gamma}{\left(1+t\sigma^2\right)\rho}$$

$$w_A^{Y-N-CO}=\frac{V}{2}$$

$$w_B^{Y-N-CO}=\frac{1}{2}\left(V\theta+\Gamma-(k-l)-\frac{\Gamma}{1+t\sigma^2}\right)$$

$$\pi_{SC}^{Y-N-CO}=\frac{M\left(V^2+(V\theta-kt+lt)^2\right)-2t^2\rho+t\left(M\left(V^2+(V\theta-kt+lt)^2\right)-2t^2\rho\right)\sigma^2+Mt\sigma^4}{2\left(\rho+t\rho\sigma^2\right)}$$

12. The supply chain uses the solution of information sharing in the case of delay strategy (Y-DE):
    (1) $U_A^{Y-DE}>U_B^{Y-DE}$

$$p_A^{Y-DE}=\frac{6\delta+t(1-\delta)(1-k\delta)-\theta+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}-\frac{t\Gamma(1+\delta)(2+\delta)\theta^2\sigma^2}{1+t\sigma^2}-\delta\theta\left(4+\delta-5\Gamma\left(1-\frac{1}{1+t\sigma^2}\right)\right)}{8\delta-2(1+\delta)^2\theta}$$

$$p_B^{Y-DE}=\frac{2t\delta(3+k\delta)-t(1+\delta)(1+(2+k)\delta)\theta}{2\delta\left(4\delta-(1+\delta)^2\theta\right)}-$$
$$\frac{1}{2\delta\left(4\delta-(1+\delta)^2\theta\right)}\left(\frac{\theta\left(\theta-\delta\left(5-3\theta+\delta(1-2\theta)\right)\right)+t\left(\theta-\delta(5+6\Gamma+\delta)+\left(\Gamma+\Gamma\delta(4+\delta)+\delta(3+2\delta)\right)\theta\right)\sigma^2}{1+t\sigma^2}\right)$$

$$q_A^{Y-DE}=\frac{\delta(2-\theta+\Gamma\theta)+\frac{\Gamma(1-\delta)\theta}{1+t\sigma^2}-t(1+\delta)(1-k\delta)-(1+\Gamma)\theta}{8\delta-2(1+\delta)^2\theta}$$

$$q_B^{Y-DE}=\frac{\delta\left(2t(1-k\delta)+\theta\left(1-\delta+\frac{t\Gamma(2-\theta-\delta\theta)\sigma^2}{1+t\sigma^2}\right)\right)}{2\theta\left(4\delta-(1+\delta)^2\theta\right)}$$

$$w_A^{Y-DE}=\frac{1}{2}\left(1+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$w_B^{Y-DE}=\frac{t-kt\delta+\theta+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}}{2\delta}$$

$$\pi_R^{Y-DE}=\frac{t(1-\delta)(1-k\delta)\theta+t^2\left((1-k\delta)^2-16\delta\theta+4(1+\delta)^2\theta^2\right)+\frac{(1-\theta)\theta\left(\delta+t\delta\sigma^2+t\theta\sigma^4\right)}{1+t\sigma^2}}{4\theta\left(4\delta-(1+\delta)^2\theta\right)}$$

$$\pi_M^{Y-DE}=\frac{t^2(1-k\delta)^2+t(1-\delta)(1-k\delta)\theta+\frac{(1-\theta)\theta\left(\delta+t\delta\sigma^2+t\theta\sigma^4\right)}{1+t\sigma^2}}{2\theta\left(4\delta-(1+\delta)^2\theta\right)}$$

$$\pi_{SC}^{Y-DE}=\frac{t(1-\delta)(1-k\delta)\theta+t^2\left((1-k\delta)^2-16\delta\theta+4(1+\delta)^2\theta^2\right)+\dfrac{(1-\theta)\theta\left(\delta+t\delta\sigma^2+t\theta\sigma^4\right)}{1+t\sigma^2}}{4\theta\left(4\delta-(1+\delta)^2\theta\right)}+$$

$$\frac{t^2(1-k\delta)^2+t(1-\delta)(1-k\delta)\theta+\dfrac{(1-\theta)\theta\left(\delta+t\delta\sigma^2+t\theta\sigma^4\right)}{1+t\sigma^2}}{2\theta\left(4\delta-(1+\delta)^2\theta\right)}$$

(2) $U_A^{Y-DE}<U_B^{Y-DE}$

$$p_A^{Y-DE}=\frac{\begin{pmatrix}-\delta^2\left(1-kt+t(1-kt+\Gamma)\sigma^2\right)+\theta\left(t-\theta+t(t+\Gamma-\theta-2\Gamma\theta)\sigma^2\right)\\+\delta\left(6-t-4\theta-kt\theta+t\left(6-t+5\Gamma-(4+kt+3\Gamma)\theta\right)\sigma^2\right)\end{pmatrix}}{2\left(2\delta(2-\theta)-\delta^2-\theta^2\right)\left(1+t\sigma^2\right)}$$

$$p_B^{Y-DE}=\frac{2t\delta(3+k\delta)-t(1+\delta)\left(1+(2+k)\delta\right)\theta}{2\delta\left(4\delta-(1+\delta)^2\theta\right)}-$$

$$\frac{1}{2\delta\left(4\delta-(1+\delta)^2\theta\right)}\left(\frac{\theta\left(\theta-\delta\left(5-3\theta+\delta(1-2\theta)\right)\right)+t\left(\theta-\delta(5+6\Gamma+\delta)+\left(\Gamma+\Gamma\delta(4+\delta)+\delta(3+2\delta)\right)\theta\right)\sigma^2\right)}{1+t\sigma^2}\right)$$

$$q_A^{Y-DE}=\frac{\delta(2-\theta+\Gamma\theta)+\dfrac{\Gamma(1-\delta)\theta}{1+t\sigma^2}-t(1+\delta)(1-k\delta)-(1+\Gamma)\theta}{8\delta-2(1+\delta)^2\theta}$$

$$q_B^{Y-DE}=\frac{\delta\left(2t(1-k\delta)+\theta\left(1-\delta+\dfrac{t\Gamma(2-\theta-\delta\theta)\sigma^2}{1+t\sigma^2}\right)\right)}{2\theta\left(4\delta-(1+\delta)^2\theta\right)}$$

$$w_A^{Y-DE}=\frac{1}{2}\left(1+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$w_B^{Y-DE}=\frac{t-kt\delta+\theta+\dfrac{t\Gamma\theta\sigma^2}{1+t\sigma^2}}{2\delta}$$

$$\pi_R^{Y-DE}=\frac{t(1-\delta)(1-k\delta)\theta+t^2\left((1-k\delta)^2-16\delta\theta+4(1+\delta)^2\theta^2\right)+\dfrac{(1-\theta)\theta\left(\delta+t\delta\sigma^2+t\theta\sigma^4\right)}{1+t\sigma^2}}{4\theta\left(4\delta-(1+\delta)^2\theta\right)}$$

$$\pi_M^{Y-DE}=\frac{t^2(1-k\delta)^2+t(1-\delta)(1-k\delta)\theta+\dfrac{(1-\theta)\theta\left(\delta+t\delta\sigma^2+t\theta\sigma^4\right)}{1+t\sigma^2}}{2\theta\left(4\delta-(1+\delta)^2\theta\right)}$$

$$\pi_{SC}^{Y-DE}=\frac{t(1-\delta)(1-k\delta)\theta+t^2\left((1-k\delta)^2-16\delta\theta+4(1+\delta)^2\theta^2\right)+\frac{(1-\theta)\theta\left(\delta+t\delta\sigma^2+t\theta\sigma^4\right)}{1+t\sigma^2}}{4\theta\left(4\delta-(1+\delta)^2\theta\right)}+$$

$$\frac{t^2(1-k\delta)^2+t(1-\delta)(1-k\delta)\theta+\frac{(1-\theta)\theta\left(\delta+t\delta\sigma^2+t\theta\sigma^4\right)}{1+t\sigma^2}}{2\theta\left(4\delta-(1+\delta)^2\theta\right)}$$

13. The supply chain uses the solution of information sharing in the case of new technology of big data (Y-NEW):

$$BCB=b/c:$$

$$p_A^{Y-NEW}=\frac{3}{4}\left(1+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$p_B^{Y-NEW}=\frac{1}{4}\left(3b+c+(3+k)t+3\theta\left(1+\Gamma-\frac{\Gamma}{1+t\sigma^2}\right)\right)$$

$$q_A^{Y-NEW}=\frac{1-b+c-t+kt-\theta}{4(1-\theta)}$$

$$q_B^{Y-NEW}=\frac{b-c+(1-k)t+\frac{t\Gamma(1-\theta)\theta\sigma^2}{1+t\sigma^2}}{4(1-\theta)\theta}$$

$$w_A^{Y-NEW}=\frac{1}{2}\left(1+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$w_B^{Y-NEW}=\frac{1}{2}\left(b-c+t-kt+\theta+\frac{t\Gamma\theta\sigma^2}{1+t\sigma^2}\right)$$

$$\pi_R^{Y-NEW}=\frac{1}{16}\left(1-16t^2+\frac{(b-c+t-kt)^2}{1-\theta}+\frac{(b-c+t-kt)^2}{\theta}+\frac{t\theta\sigma^4}{1+t\sigma^2}\right)+F$$

$$\pi_M^{Y-NEW}=\frac{(b-c+t-kt)^2+(1-\theta)\theta+t\left((b-c+t-kt)^2+\theta-\theta^2\right)\sigma^2+t(1-\theta)\theta^2\sigma^4}{8(1-\theta)\theta\left(1+t\sigma^2\right)}-F$$

$$\pi_{SC}^{Y-NEW}=\frac{1}{16}\left(1-16t^2+\frac{(b-c+t-kt)^2}{1-\theta}+\frac{(b-c+t-kt)^2}{\theta}+\frac{t\theta\sigma^4}{1+t\sigma^2}\right)+$$

$$\frac{(b-c+t-kt)^2+(1-\theta)\theta+t\left((b-c+t-kt)^2+\theta-\theta^2\right)\sigma^2+t(1-\theta)\theta^2\sigma^4}{8(1-\theta)\theta\left(1+t\sigma^2\right)}$$

Appendix B. Proof of Propositions

Appendix B.1. Proposition 1

$$c_B^N - c_B^Y = \frac{4t(1-\theta)\theta\left(1+t\sigma^2\right)}{1-k+\left((1-k)t+2\Gamma(1-\theta)\theta\right)\sigma^2} - \frac{4t(1-\theta)\theta\left(1+t\sigma^2\right)}{1-k-\left((1-k)t+\Gamma(1-\theta)\theta\right)\sigma^2}.$$

$$\Rightarrow c_B^N < c_B^Y$$

Appendix B.2. Proposition 2

$$\pi_R^N - \pi_R^Y = \frac{1}{16}\left(1+\frac{t^2\left(1-(2-k)k-16(1-\theta)\theta\right)}{(1-\theta)\theta}+\frac{4t\theta\sigma^4}{1+t\sigma^2}\right)-\frac{1}{16}\left(1+\frac{t^2\left(1-(2-k)k-16(1-\theta)\theta\right)}{(1-\theta)\theta}+\frac{t\theta\sigma^4}{1+t\sigma^2}\right)$$

$$=\frac{3t\theta\sigma^4}{16\left(1+t\sigma^2\right)}$$

$$\Rightarrow \pi_R^N > \pi_R^Y$$

$$\pi_M^N - \pi_M^Y = \frac{1}{8}\left(1+\frac{(1-k)^2 t^2}{(1-\theta)\theta}\right)-\frac{1}{8}\left(1+\frac{(1-k)^2 t^2}{(1-\theta)\theta}+\frac{t\theta\sigma^4}{1+t\sigma^2}\right)$$

$$=-\frac{t\theta\sigma^4}{8\left(1+t\sigma^2\right)}$$

$$\Rightarrow \pi_M^N < \pi_M^Y$$

$$\pi_{SC}^N - \pi_{SC}^Y = \frac{1}{16}\left(3+\frac{t^2\left(3(1-k)^2-16(1-\theta)\theta\right)}{(1-\theta)\theta}+\frac{4t\theta\sigma^4}{1+t\sigma^2}\right)-\frac{1}{16}\left(3+\frac{t^2\left(3(1-k)^2-16(1-\theta)\theta\right)}{(1-\theta)\theta}+\frac{3t\theta\sigma^4}{1+t\sigma^2}\right)$$

$$=\frac{t\theta\sigma^4}{16+16t\sigma^2}$$

$$\Rightarrow \pi_M^N > \pi_M^Y$$

Appendix B.3. Proposition 3

The proof is same as Proposition 2, which omits this section.

Appendix B.4. Proposition 4

The proof is same as Proposition 2, which omits this section.

Appendix B.5. Proposition 5

The proof is same as Proposition 2, which omits this section.

Appendix B.6. Proposition 6

The proof is same as Proposition 2, which omits this section.

Appendix B.7. Proposition 7

The proof is same as Proposition 2, which omits this section.

Appendix B.8. Proposition 8

The proof is same as Proposition 2, which omits this section.

Appendix B.9. Proposition 9

The proof is same as Proposition 2, which omits this section.

Appendix B.10. Proposition 10

The proof is same as Proposition 2, which omits this section.

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