Financing Strategies for a Fashionable Product Supply Chain with Capital Constraints under Blockchain Technology

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Abstract. The major members of the fashionable product supply chain are small and medium-sized enterprises, which have difficulties in obtaining loans. However, the traditional supply chain finance is relatively difficult for them. Blockchain technology can provide feasible financing methods for small and medium-sized enterprises. Hence, we establish a multi-level Stackelberg game and analyze equilibrium strategies of members in supply chain. Through analysis, we find that equilibrium strategies of members are subjected to supplier's discounts rate. In addition, the conditions for choosing blockchain-supported finance mode heavily rely on the marginal blockchain cost and disutility of customers' perceived value of fashionable products.

Keywords: Supply chain finance, Fashionable product supply chain, Blockchain technology, Stackelberg game.

1 Introduction

With the rapid development of economy and technology, the fashion industry also faces a rapidly changing market environment, which means that members of fashionable supply chain need to respond in a timely manner according to market trend. However, the upstream and downstream of the fashionable product supply chain with product retailers as the core enterprises often connect several small and medium-sized enterprises (SMEs). SEMs as a relatively weak link in the fashionable supply chain, are often troubled by problems such as getting enough capitals for production, cash flow analyses, supply chain setting for payment terms and so on. The traditional supply chain is heavily on financial service providers to support its supply chain finance (SCF). Well-established banks and financial service providers play an important role. Due to SMEs' unguaranteed credits and certification, SMEs are faced with the problem of expensive financing service fees.

With the rapid development of blockchain technology, supply chain members can financially connect to one another by bypassing the banks. The blockchain technology is characterized with immutability, transparency, traceability and verifiability [1]. Different from the traditional supply chain finance, on the one hand, SMEs can pass on the

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credit of the core enterprise and obtain credit guarantees using blockchain technology, which reduce operational risk. On the other hand, the supply chain members do not need to rely on the traditional bank and hence the respective service fees are no longer needed [2]. However, operations with blockchain are not free and the blockchain marginal costs are incurred.

Based on the above background, this paper establishes a game analysis to build models for a fashionable product supply chain with capital constraints with or without blockchain technology. The equilibrium strategies of members in supply chain under the two models are discussed. Then, the critical conditions for choosing supply chain financing modes using blockchain technology are obtained. This study contributes to the practice by providing some suggestions for the members of the fashionable product supply chain to make decisions on supply chain financing modes.

2 Model

2.1 Problem description and assumption

We use R, M and S to denote the retailer, the manufacturer and the supplier, respectively. In addition, $j = T, B$ are used to represent two different supply chain financing modes. Specifically, $j = T$ denotes the traditional bank credit guarantee finance mode and $j = B$ denotes the blockchain-supported finance mode.

In terms of the two different supply chain finance modes, the supplier offers primary goods to the manufacturer at different price and uniform cost c_s. That is, the supplier provides goods for the manufacturer at a discounted wholesale price λw_s under model T while at a wholesale price w_s without discount under model B. The manufacturer processes goods at cost c_m and increases Δp_m to the wholesale price. Now, as the leader, the retailer makes an order quantity q based on the market demand and increases Δp_r. Hence, the retail price is $p = w_s + \Delta p_m + \Delta p_r$. For customers, we assume the fashionable product market is a price-sensitive market. Hence, following the assumption of Choi, we assume the demand function is $q = a - bv,\ a, b > 0$, where a represents the maximum demand in the market, v represents consumers' perceived cost of the purchased fashionable products and b represents the sensitivity coefficient of sales quantities to the perceived cost. Assumption 1: Under mode T, consumers will be skeptical about the authenticity of fashionable products. Hence, this will lead to a negative effect on the perceived value of consumers [3]. This negative effect mainly derives from authenticity of fashionable products η^T. Hence, under mode T, consumers' perceived cost is $v = p + \eta^T$. Assumption 2: Under mode B, we assume all players in the supply chain choose to participate in blockchain platform can be trusted by the bank. We assume all players need to bear the marginal blockchain cost c_B [4][5]. In addition, we assume $\eta^B = 0$ and $v = p$ [6].

2.2 Model setting

1) The traditional bank credit finance mode: Based on the above analysis, under model T, the manufacturer′s profit is $\Pi_{\mathrm{M}}^{T}=\left[\Delta p_{M}^{T}-c_{M}\left(1+r^{T}\right)-c_{B}\right]q_{R}^{T}+(1-\lambda)w_{S}^{T}q^{T}$ [5]. Act as the leader in the Stackelberg game, anticipating the optimal responses of both the manufacturer and the supplier, the retailer sets an optimal incremental price Δp_{R}^{T} to maximize its profit. Besides, the cost of sales each product for the retailer is c_{R}. Thus, the retailer's profit is: $\Pi_{R}^{T}=(\Delta \mathrm{p}_{\mathrm{R}}^{T}-c_{\mathrm{R}})q_{R}^{T}$.

2) The blockchain-supported finance mode: Under mode *B*, we can derive the retail price, demand and profit functions of the retailer as follows: $p_{R}^{B}=\omega_{S}^{B}+\Delta p_{M}^{B}+\Delta p_{R}^{B}$, $q_{R}^{B}=a-b\left(\omega_{S}^{B}+\Delta p_{M}^{B}+\Delta p_{R}^{B}\right)$, $\Pi_{R}^{B}=\left(\Delta p_{R}^{B}-c_{R}-c_{B}\right)q_{R}^{B}$ [3]. In addition, the profit functions are given by $\Pi_{S}^{B}=\left[\Delta p_{S}^{B}-c_{S}\left(1+r^{B}\right)-c_{B}\right]q_{R}^{B}$ and $\Pi_{M}^{B}=\left[\Delta p_{M}^{B}-c_{M}\left(1+r^{B}\right)-c_{B}\right]q_{R}^{B}$ [6].

3 Model Analysis

By solving the game model through the backward induction, we can obtain the following equilibrium strategies under model T as described in Lemma 1.

Lemma 1. Under mode T, the equilibrium strategies of each player are

$$\Pi_{\mathrm{S}}^{T^{*}}=\lambda\left\{a-b\left[\left(c_{S}+c_{M}\right)\left(r^{T}+1\right)+c_{R}+\eta^{T}\right]\right\}^{2}/16b\left(\lambda+1\right)^{2}$$

$$\Pi_{\mathrm{M}}^{T^{*}}=\left\{a-b\left[\left(c_{S}+c_{M}\right)\left(r^{T}+1\right)+c_{R}+\eta^{T}\right]\right\}^{2}/16b\left(\lambda+1\right)$$

$$\Pi_{\mathrm{R}}^{T^{*}}=\left\{a-b\left[\left(c_{S}+c_{M}\right)\left(r^{T}+1\right)+c_{R}+\eta^{T}\right]\right\}^{2}/8b\left(\lambda+1\right)$$

Lemma 2. Under mode *B*, the equilibrium strategies of each player are

$$\Pi_{\mathrm{S}}^{B^{*}}=\left\{a-b\left[\left(c_{S}+c_{M}\right)\left(r^{B}+1\right)+c_{R}+3c_{B}\right]\right\}^{2}/64b,$$

$$\Pi_{M}^{B^{*}}=\left\{a-b\left[\left(c_{S}+c_{M}\right)\left(r^{B}+1\right)+c_{R}+3c_{B}\right]\right\}^{2}/32b,$$

$$\Pi_{R}^{B^{*}}=\left\{a-b\left[\left(c_{S}+c_{M}\right)\left(r^{B}+1\right)+c_{R}+3c_{B}\right]\right\}^{2}/16b$$

Proposition **1.** If $\eta^{T}>\eta_{1}^{\prime T}$ and $0\le c_{B}\le c_{B1}^{\prime}$, the supplier should choose blockchain-supported finance mode $\left(\Pi_{\mathrm{S}}^{B^{*}}\ge\Pi_{\mathrm{S}}^{T^{*}}\right)$; if $\eta^{T}>\eta_{2}^{\prime T}$ and $0\le c_{B}\le c_{B2}^{\prime}$, the manufacture and retailer should choose blockchain-supported finance mode $\left(\Pi_{M}^{B^{*}}\ge\Pi_{M}^{T^{*}}\text{ and }\Pi_{R}^{B^{*}}\ge\Pi_{R}^{T^{*}}\right)$.

Proposition 1 shows that when the disutility of customers' perceived value for fashionable products under mode T is higher than a certain level (i.e., $\eta^T > \eta_1'^T$), if the marginal blockchain cost is lower than a certain level, the supplier will be more likely to choose the blockchain platform finance mode. This reason is that faced with serious disutility of customers' perceived value for fashionable products, blockchain platform has the advantage of strengthening customers' trust attitude to fashionable products. In addition, the supplier does not need to bear heavy blockchain cost. Hence, the supplier will choose blockchain platform finance mode. Similarly, we can find that if the disutility of customers' perceived value for fashionable products under mode T is higher than a certain level (i.e., $\eta^T > \eta_2'^T$), the retailer and the manufacture can achieve higher profits at the same time if the marginal blockchain cost is lower than a certain level (i.e., $0 \le c_B \le c'_{B1}$). In reality, according to Forbes, noble fashion brands such as "Dior" and "Louis Vuitton" have started to participate in blockchain platform to realize directly transaction between the sellers and buyers.

Proposition 2. If $0 \le c_B \le c'_{B3}$, $\eta^T > \eta_3'^T$, the entire supply chain would have better profits $\left(\Pi^{B^*} \ge \Pi^{T^*}\right)$.

Proposition 2 shows that the expected profit for the entire supply chain under blockchain technology is higher than the traditional bank finance mode, if the interest rate charged by the traditional banking services is high. This is because that on the one hand, blockchain technology can strengthen trust between players. As a result, this mode can bring more customers for supply chain. On the other hand, blockchain technology makes the supplier and the manufacturer get credit guarantee from the dominant retailer. Consequently, both of them can get loans from the bank directly. On the contrary, if the interest rate is not high and the marginal blockchain cost is high, it is not supported to choose blockchain-supported finance mode.

4 Conclusion

This paper constructs a fashionable product supply chain consisting of retailers as leaders and capital-constrained manufacturers and suppliers. We establish a Stackelberg game model that the fashionable product supply chain with or without blockchain technology. Through analysis, the optimal strategy of the decision-maker is obtained. We also further analyze the conditions for each decision-maker in the fashionable product supply chain to choose blockchain-supported supply chain finance mode. The theoretical implications and practical implications are respectively discussed as follows.

For the theoretical implications, when the market's maximum demand rises, all members will adopt a higher price strategy to increase the unit product profit, so as to achieve an increase in revenue. When the perceived price sensitivity of consumers increases, the three decision makers will also lower their own prices and exchange lower prices for a larger sales market. Moreover, the low marginal blockchain cost make the members of the supply chain active in using blockchain technology and in this situation, the profit of the entire supply chain can be improved at the same time.

However, there are some limitations in the work of this paper. The constructed model does not consider the time value of funds, and assumes that all participants in the supply chain are risk-neutral. In the future, the operation of the supply chain can be further discussed considering the time value of funds and risk aversion.

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