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Research on Coordination Management of Green Supply Chain under BI Insurance

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ABSTRACT. *This paper is based on the Stackelberg model to study the strategic choices of suppliers and retailers in the context of a predictable increase in market demand. Considering the basic state separately, taking the volume discount pricing measures separately, purchasing the BI insurance separately, and combining, the research shows that the purchase of BI insurance can effectively suppress the drawbacks that the volume discount pricing strategy may cause the transaction volume to exceed the market demand. In the case of an increase in supply chain disruption, the combination of BI insurance and volume discount pricing strategies is the optimal strategy choice for a two-node supply chain.*

KEYWORDS: *increased demand, business interruption insurance, volume pricing discount strategy*

1. Introduction

With the rapid development of society, various shopping festivals such as 618, Double Eleven and Double Twelve emerged, which made the production of goods face new challenges of sudden increase in demand; various national policy changes and increased demand for post-war goods. This situation will cause a sudden increase in demand for goods, which in turn will lead to potential problems such as demand disruption.

At present, the research on supply chain disruption is divided according to management strategy, which is roughly distributed in financial strategy and operational strategy. The operational strategy mainly refers to demand management (Tomlin2009) [1], holding inventory, and backup production. The financial strategy includes options, financial assistance, and the focus of this paper's research—insurance. Financial assistance mainly includes delayed payments, loans, and financial assistance. It focuses on the effectiveness of financial aid in helping upstream companies restore production or improve reliability, as well as the relative value of other strategies, Li, Zhen, Qi and Cai (2016) [2]. Tang Gurnani and Gupta (2014) [3]. The research on options mainly focuses on downstream companies to deal with supply chain disruption risks by purchasing options or signing option contracts with upstream suppliers, mainly to study the value of options and strategic choices with other strategies. Li and Wang (2015) [4]. In terms of BI insurance, it mainly studies the relationship between business interruption insurance, trade credit insurance and operational strategies. Such as BI insurance and inventory, emergency procurement, backup transportation and other complementary and alternative relationships. Li, Zhen and Cai (2016) [5], Zhen, Li Cai and Shi (2016) [6]. In the volume discount pricing strategy, we studied how to use the AQDP strategy in the two-node supply chain to reduce the supply chain interruption measures as much as possible. Huan Zhang, Yang Liu and J Huang (2015) [7]; Chen Xu [8] earlier considered the volume discount pricing strategy for perishable products of customer demand information; Wei Tao and Wang Y et al. [9] combined volume discount pricing strategy with free ordering strategy Based on the discontinuity of the discount function, a numerical algorithm for optimal free shipping minimum order quantity is established by inverse induction. No scholars have combined BI insurance and volume discount pricing strategies to discuss research.

This paper combines BI insurance and AQDP to study supply chain coordination issues involving a supplier and a retailer, with the aim of mitigating the potential for supply chain disruptions. Suppliers dominate the game throughout the game. The problem is described as follows: The product studied in this paper has a short life cycle, and its trading volume in the supply chain is a decreasing function related to the retail price. The supplier formulates the production plan and the wholesale price according to the market demand forecast. The retailer decides Single wholesale volume and retail price.

Research features and innovations: Financial strategies such as insurance have little research on managing supply chain disruptions, lacking research on the relationship between financial strategies and operational strategies; introducing business interruption insurance – a financial tool based on operational management A perspective that intersects with the financial discipline; From the perspective of the entire supply chain, the risk sharing between the upstream and downstream supply chains is studied; the business interruption insurance and the volume discount pricing strategy are combined to solve the problem of rapid increase in market demand in line with the background of the times.

2. Model hypothesis

This paper mainly studies the use of bulk discount pricing strategy alone, the use of BI insurance alone, and the combination of the two strategies. Under what circumstances, the three models will play the biggest role, that is, the three modes are applicable to which case, and which model of strategy is more beneficial to the supply chain. Based on this, the paper makes the following assumptions:

1. Allow interrupted destruction of inventory;

2. Unlike the newsboy model, assume that the retailer is suffering from slow sales, losses rather than returning the goods;

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3. All damage incidents are within the scope of BI insurance.

Table 1 Parameter settings

Supplier per unit of production cost	v
Supplier out-of-stock cost per unit	g
Supply chain loss	IL
Price per unit transaction	r
Retail price per unit	p
Market size	D
Price sensitivity coefficient	b
Trading volume	Q=D-bp
Retailer inventory cost	h
BI insurance deductible	T
Maximum limit for BI insurance	L

3. Strategic Analysis

3.1 Basic model

In the strategy model to be studied in this paper, the profit of suppliers and retailers will be calculated separately. The basic profit of the supplier is expressed by the difference between the transaction profit of the supplier and the out-of-stock cost of the retailer. It is mainly due to the underestimation of the sudden increase in market demand, or the fact that its own production capacity has not met the surge in the market, resulting in the actual transaction volume being lower than the market demand. And considering that in the actual market transaction process, the supplier has obvious loss of goodwill relative to the retailer, so it is different from the retailer's stock-out loss, and the shortage of the part of the supplier includes a part of the goodwill cost. The supplier's stock-out cost is expressed by g. At this time, π_s is used to represent the profit of the supplier under the basic situation, and the profit of the supplier is expressed by the corresponding functional relationship:

$$\pi_s = Q(r-v) - g(D-Q)$$

In addition, this paper mainly considers the supply chain disruption caused by the sudden increase in market demand, ignoring the inventory cost that may occur in the process of commodity sales. Therefore, the inventory cost is not included in the profit model. The retailer's profit is basically represented by π_r. At this time, the retailer's profit is expressed by the corresponding functional relationship:

$$\pi_r = Q(p-r) - p(D-Q)$$

In the perfect supply chain, the sum of the profits of the retailer and the supplier is the profit of the entire supply chain, and the profit of the entire supply chain is obtained by omitting the terminal and the top commodity trading profit after the

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intermediate nodes. It follows that the profit loss (IL) of the research problem in this paper is expressed by the corresponding functional relationship:

$$IL = Q(p - v) - (\pi_s + \pi_r) = (g + p)(D - Q) = bp(g + p)$$

The retailer's profit function is used to guide the transaction volume Q, and with the relationship between the retail price p and the transaction volume, the optimal retail price that the retailer should set is: p*= (D+br)/4b.

In the above, it is mentioned by the retailer to determine the retail price and wholesale volume of each transaction. Therefore, in the basic case, the optimal wholesale price of the retailer can be derived from the optimal retail price: Q*= (3D-br) /4.

According to the game theory, suppliers as the party with complete and perfect information can make decisions on their optimal wholesale price according to the optimal wholesale quantity that the retailer will propose. Then, substituting Q* into the supplier's profit function, the optimal transaction price determined by the supplier is: r*=3D/2b+ (v-g)/2.

3.2 Volume discount pricing strategy

This section conducts a separate study of volume discount pricing strategies. Quoting Tang Q et all's volume discount pricing method [10], first construct a linear, downward-sloping pricing formula for wholesale price of supplier units: r(Q)=R-dQ, then the retailer's payment function is the supplier's volume discount pricing. The formula is: (R-dQ) Q, where R, the vertical axis intercept of the wholesale price function, is the largest wholesale price. d is the slope or discount factor of the function, and Q is the number of wholesale products.

Hypothesis 1: Introducing a volume discount pricing strategy can effectively increase the volume of transactions.

In the study of Zhou D and others [11], when introducing the wholesale price insurance contract, the supplier and the retailer respectively bear the risk of interruption of the ratio of a and 1-a, and this idea is introduced into the research of this paper, when the supplier gives the retailer ADQP's strategic incentives, at the same time, retailers and suppliers bear a certain percentage of interruption losses. The profit of the supplier is represented by π_{s1}. Then, the profit of the supplier at this time is the difference between the transaction profit and the corresponding loss, which is expressed by the corresponding function:

$$\pi_{s1} = ((R - dQ) - v)Q - aIL$$

When a supplier adopts a volume discount pricing strategy for a retailer, the retailer is likely to make a large purchase in order to obtain a lower price, thereby generating inventory costs. Using π_{r1} to represent the retailer's profit at this time, then the retailer's profit is expressed as a corresponding function:

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$$\pi_{r1} = [p - (R - dQ)]Q - (1 - a)IL - h(Q - D)$$

The volume discount pricing strategy is adopted to increase the profit of the entire supply chain node $\pi'=\pi_{s1}+\pi_{r1}$. Therefore, in this section, it is assumed that both parties proceed from the overall benefit of the supply chain to make joint decision. The maximum wholesale price is:

$$R_1^* = (v + dQ_1^*)Q_1^* + \frac{aIL}{Q_1^*}$$

Substituting R_1* into π' and deriving the optimal value for Q, the optimal transaction amount at this time is Q_1*=D+bg/2

Compared with the optimal wholesale quantity in the basic strategy, ΔQ_1=Q_1*-Q*= (D+bg/2)-((3D-br)/4)>0.

According to the calculation results, the use of the volume discount pricing strategy significantly increases the volume of goods traded between suppliers and retailers, increases the circulation of goods, and brings effective profits to the supply chain. Hypothesis 1 is established.

At the same time, however, the optimal transaction volume Q_1* using the volume discount pricing strategy alone is also significantly larger than the market demand D, and the loss of the market demand portion will cause the retailer to have many uncertain factors when signing the transaction contract. The completion rate is greatly reduced. Therefore, while increasing the transaction volume, there are certain drawbacks to using the batch discount pricing strategy alone.

3.3 BI insurance strategy

In the entire Stackelberg game model, the supplier dominates. If the supplier does not consider the entire supply chain to be optimal, but from its own point of view, the supplier may choose to purchase the BI insurance strategy separately to ensure that the loss can be compensated in time when the market demand increases. Suppliers and retailers each bear their own losses.

In the study of BI insurance, this section draws on the insurance pricing methods proposed by kuzak and Larsn [12]: premium = annual loss + cost burden + risk burden. Since the focus of this paper is not to study the optimal BI insurance strategy, the sum of the annual average loss and the cost burden is roughly classified as a fixed value, expressed by m_1, and the risk weighting coefficient is represented by the letter m_2. Therefore, the premium of BI insurance can be expressed as: $P=m_1+m_2IL$ ($m_1>1$, $0<m_2<1$).

The deductible of BI insurance is indicated by the letter T. When the loss IL is less than the deductible, the insurance company will not pay, and the loss will be borne by the supplier. Therefore, this paper only considers the loss is greater than the deductible; when the loss is greater than In the case of deductible, the relationship between the difference between the loss and the deductible and the

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maximum limit of the insurance company is further discussed. The difference between the loss and the deductible is expressed as M, and the maximum limit of the insurance company is L. M>L and M<L under the circumstances of the supplier's profit changes. The insurance company's repayment is indicated by the letter R, R = min {[IL-T], L}. At this point, the supplier's profit includes the difference between the transaction profit and the stock-out loss and the difference between the insurance company's compensation and the premium that needs to be paid to the insurance company. The profit of the supplier at this time is represented by π_{s2}, and the corresponding profit is used. The function is expressed as:

$$\pi_{s2} = Q(r-v) - g(D-Q) - (m_1 + m_2\mathrm{IL}) + \min\{[\mathrm{IL}-\mathrm{T}], \mathrm{L}]\}$$

In this section, BI insurance considers the strategy adopted by the supplier alone. In actual operation, when the supplier adopts BI insurance, the transaction price may be reduced accordingly for the retailer. However, in the model study, we assume that the vendor's separate use of BI insurance will not affect the retailer's profit. For the convenience of analysis, we use π_{r2} in this section to represent the retailer's profit, expressed as the corresponding profit function: $\pi_{r2} = Q(p-r) - p(D-Q) = \pi_r$

When M>L, the difference between loss and deductible is greater than the maximum limit of BI insurance, the supplier's expected profit is:

$$\pi_{s2} = Q(r-v) - g(D-Q) - (m_1 + m_2\mathrm{IL}) + \mathrm{L}$$

In the Stackelberg model, the supplier dominates, assuming that the supplier has complete information. According to the dual game idea, the supplier first calculates the optimal transaction volume based on the overall interest, and based on this, formulates its own wholesale price. From the overall interests of the supply chain, the optimal transaction volume obtained by the supplier is:

$$Q'_{21} = \mathrm{D} + \frac{bg}{2} + \frac{D-2Q}{2m_2} = Q_1^* + \frac{D-2Q}{2m_2}$$

Let M=D-2Q, then E (M) = D-2Q*=D-(3D-br)/2= (-D-br)/2<0

Therefore, there is $Q_{21}'<Q_1^*$, that is, when the estimated interruption loss is large, or the compensation for BI insurance is small, the tradeoff is to use BI insurance or volume discount pricing strategy. If the supplier decides to use the volume discount pricing strategy, Will lead to a larger transaction volume than BI insurance. However, the volume discount pricing strategy itself will cause retailers to purchase large quantities in pursuit of low transaction prices, resulting in a larger transaction volume than market demand. At this point, it is necessary to further judge the positive and negative of ($M/2m_2$+bg/2), so that N=$2m_2$ bg-(D+br), when N>0, take a smaller Q_{21}', that is, take BI insurance; When N<0, a larger Q_1^* should be adopted, that is, a bulk discount pricing strategy is adopted. In the actual situation, if the compensation for BI insurance is small, it is safer to adopt a volume discount pricing strategy.

When M < L, that is, the difference between the loss and the deductible is less than the maximum limit, the supplier's expected profit is:

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$$\pi_{s2} = Q(r-v) - g(D-Q) - (m_1 + m_2 IL) + (IL - T)$$

The optimal trading volume at this time is: $Q'_{22} = D + \frac{bg}{2} - \frac{D-2Q}{2(1-m_2)} = Q_1^* - \frac{D-2Q}{2(1-m_2)}$

In the case of a sudden increase in demand, each node in the supply chain will make the transaction volume close to the market demand as much as possible, so there is D-2Q<0. According to the value range of m_2, there is $1-m_2>0$, and $Q_{22}' > Q_1^*$. At this time, BI insurance has a large amount of compensation, and the transaction volume of BI insurance is larger than that of the volume discount pricing strategy alone, so suppliers will be more inclined to adopt BI insurance strategy.

3.4 Combination of two strategies

According to the above research, although the volume discount pricing strategy alone can increase the transaction volume, there are drawbacks that the transaction volume is greater than the market demand. When BI insurance alone can compensate for the sudden loss of market demand, the combination of these two strategies can be mutually beneficial and avoided. This section discusses this. Hypothesis 2: Buying BI insurance can effectively avoid the drawbacks of bulk discount pricing strategies.

Suppose a supplier uses a volume discount pricing strategy to stimulate retailers to increase purchases while making stop-loss measures that is, buying BI insurance to minimize the loss of stocks that may occur in undercapacity or other circumstances. At this time, the supplier's profit includes the difference between the transaction profit and the corresponding loss and the difference between the insurance company's compensation and the premiums that need to be paid to the insurance company. The supplier's profit at this time is represented by π_{s3}, and the corresponding profit is used. The function is expressed as:

$$\pi_{s3} = [(\mathrm{R} - \mathrm{dQ}) - v]Q - aIL - (m_1 + m_2\mathrm{IL}) + \min\{[\mathrm{IL} - \mathrm{T}], \mathrm{L}\}$$

At this point, the retailer's profit is the profit from the transaction minus the possible inventory cost and part of the loss that should be borne. The retailer's profit is expressed by π_{r3}, which is expressed as:

$$\pi_{r3} = [p - (\mathrm{R} - \mathrm{dQ})]Q - (1-a)IL - h(Q-D)$$

When adopting a composite strategy combining BI insurance and volume discount pricing strategies, it is still necessary to consider two situations that may occur when BI insurance is adopted. When the difference between loss and deductible is greater than the maximum limit of the insurance company, M>L, supply the profit function of the quotient is:

$$\pi_{s3} = ((R - dQ) - v)Q - aIL - (m_1 + m_2\mathrm{IL}) + \mathrm{L}$$

At this point, the supplier's profit function is used to guide Q, and when the combination of the two strategies of BI insurance and volume discount pricing is adopted, the optimal batch for M>L is:

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$$Q_{31}' = D + \frac{bg}{2} - \frac{Q}{2(1+m_2)} = Q_1^* - \frac{Q}{2(1+m_2)}$$

Let G=Q/2(1+m_2), we know that G>0, so there is $Q_{31}'<Q_1^*$. That is, the composite strategy used in combination with BI insurance and volume discount pricing strategies can appropriately reduce the wholesale volume of the bulk discount pricing strategy alone, and assume that 2 is verified.

When the difference between the loss and the BI insurance deductible is less than the insurance company's maximum limit, M < L, the supplier's profit function π_{s3} and the optimal batch Q_{32}' at this time are:

$$\pi_{s3} = ((R-dQ)-v)Q - aIL - (m_1 + m_2\text{IL}) + (\text{IL} - \text{T})$$

$$Q_{32}' = D + \frac{bg}{2} - \frac{1}{2m_2} = Q_1^* - \frac{1}{2m_2}$$

$Q_{32}'<Q_1^*$ is obtained from the value range of m_2 of $0<m_2<1$, so the assumption 2 is also true when M<L. It can be seen that the composite strategy used by BI insurance and volume discount pricing strategy can avoid the disadvantages of batch size greater than market demand to a certain extent compared to the use of batch discount pricing strategy alone.

4. Numerical simulation

In this section, we study the effects of two uncertain variables—price sensitivity coefficient b and risk weighting coefficient m_2 on the profit and transaction volume of each node in the supply chain. And referring to the parameter values in [13], the market demand obeys a uniform distribution D ~ [400, 500], p = 18, r = 15, v = 12, g = 3, h = 3.

4.1 The influence of price sensitivity coefficient b on each node's decision

4.1.1 Impact on retailers

Figure. 1 Basic strategy & insurance strategy's influences on retailers

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The plus sign and the straight line indicate the impact of the price sensitivity coefficient on the retailer's profit under the basic strategy and the BI insurance strategy, respectively.

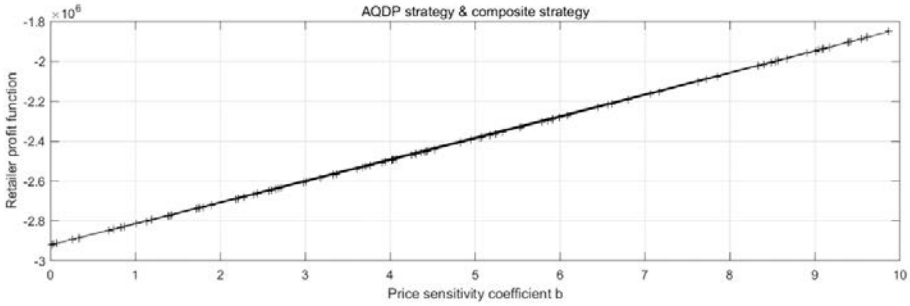

Figure. 2 AQDP strategy & composite strategy's influences on retailers

The plus sign and the straight line respectively indicate the impact of the price-sensitive coefficient on the retailer's profit under the volume discount pricing strategy and the composite strategy.

This article takes a grid approach to make the legend more intuitive. It can be seen from the above figure that in the basic strategy and the separate use of BI insurance, the price sensitivity coefficient b has a negative impact on the retailer's profit, the impact size and the impact trend are consistent, and under the premise of the assumed value, if the price sensitivity coefficient is greater than 3.5, the profit is negative, the retailer will not enter the market. The effect of the price sensitivity coefficient b on the retailer's profit when using the volume discount pricing strategy alone is consistent with the impact on the composite strategy, which is positive.

4.1.2 Impact on suppliers

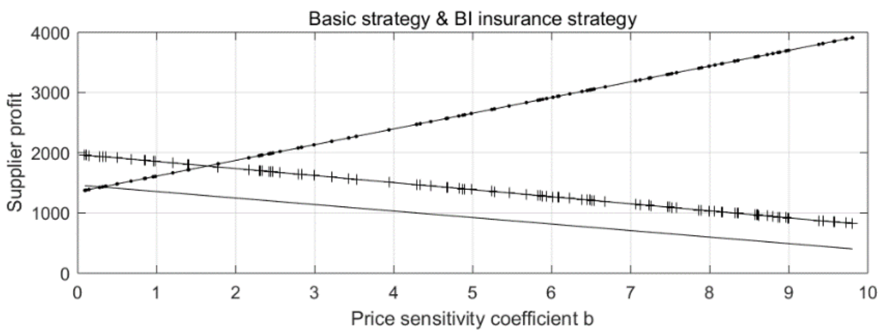

Figure. 3 Basic strategy & insurance strategy's influences on suppliers

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The line with the plus sign indicates the case where the supplier uses M>L when BI insurance is used alone, that is, the difference between the loss and the deductible is greater than the maximum limit of the BI insurance, and the price sensitivity coefficient has a negative impact on the supplier's profit. The dotted line indicates the influence of the price sensitivity coefficient on the supplier's profit when the BI insurance M<L is used alone, because when M<L, the supplier's loss will be compensated by the maximum strength, and the price sensitivity coefficient is relatively larger. The greater the compensation space that the supplier will likely get, the price sensitivity coefficient at this time becomes an influential factor for the profit of the supplier. The straight line indicates the basic strategy. Compared with the case of M>L when BI insurance is used alone, the price sensitivity coefficient under the basic strategy has a relatively flat impact on the supplier's profit. In summary, under the comparison of basic strategy and BI insurance, the use of BI insurance M<L alone is the most favorable situation for suppliers.

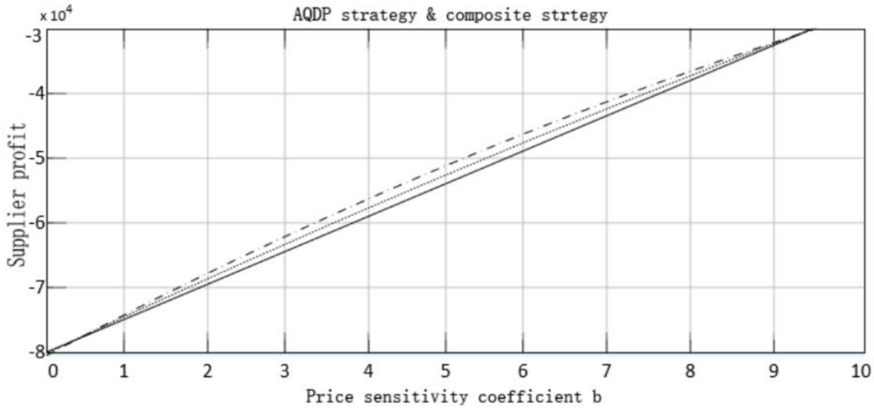

Figure. 4 AQDP strategy & composite strategy's influences on suppliers

As shown in the above figure, the dotted line indicates the influence of the price sensitivity coefficient on the supplier's profit under the batch discount pricing strategy. The solid line indicates the case of the compound strategy at M>L, and the dotted line with the dotted line indicates the case of the compound strategy with M<L. It can be seen that under these three strategies, the same price sensitivity coefficient has the same impact on the retailer, and the price sensitivity coefficient has the same effect on the supplier's profit, and has a positive impact.

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4.2 The effect of risk weighting factor m2 on trading volume

4.2.1 Impact of risk weighting factor in M>L

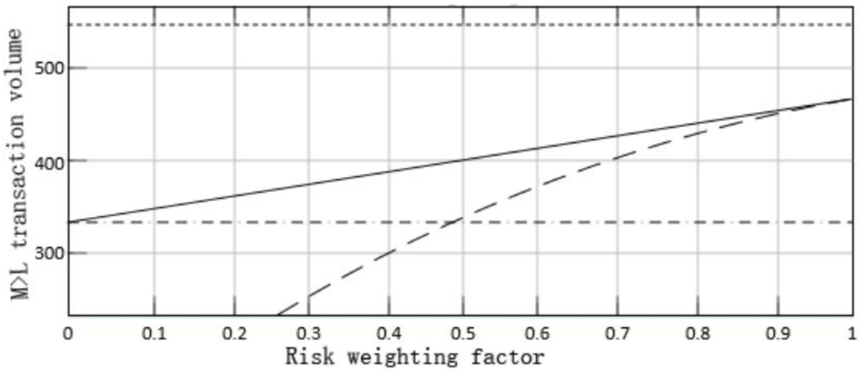

Figure. 5 The influence of risk weighting coefficient when M>L

As shown in the figure, the dotted horizontal dotted line indicates the influence of the risk weighting coefficient on the trading volume under the basic strategy. It can be seen that although the basic strategy is that the trading volume is basically not affected by the risk weighting coefficient in the legend obtained from the assumed value, when the basic strategy is adopted, trading volume is one of the lowest trading volumes of the four strategies. The dotted line indicates the situation of the volume discount pricing strategy. Since this article assumes that the demand after the sudden increase is D~ [400,500], it is consistent with the conclusion of the modeling part. When the volume discount pricing strategy is used alone, regardless of the risk weighting coefficient, the transaction the amount is likely to exceed market demand, resulting in waste of resources. The situation of BI insurance indicated by the dotted line of the line shows that BI insurance plays a significant positive role in dealing with risks. The solid line indicates the situation of the composite strategy. On the one hand, the composite strategy transforms the risk-inferior factor into a positive factor that is beneficial to the transaction volume, and avoids the disadvantage of using the volume discount pricing strategy alone to exceed the market demand. BI insurance, because risk weighting is an unknown factor, if the transaction volume is guaranteed to be the most objective under any circumstances, then the composite strategy using BI insurance and volume discount pricing strategy is the best choice.

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4.2.2 The influence of risk weighting coefficient when M<L

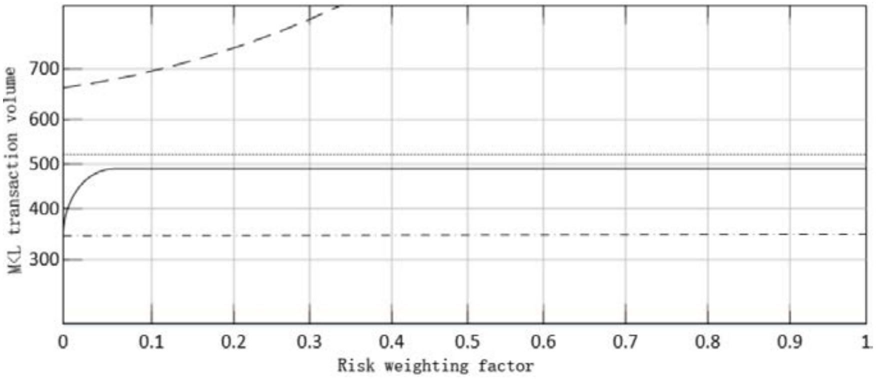

Figure. 6 The influence of risk weighting coefficient when M<L

As shown in the figure, the dotted horizontal dotted line indicates the influence of the risk weighting coefficient on the trading volume under the basic strategy, the dotted line indicates the situation of the bulk discount pricing strategy, the line insurance indicates the case of BI insurance, and the solid line indicates the situation of the composite strategy. The only difference from M>L is that the risk weighting coefficient has almost the same effect on the transaction volume when M<L is used separately for the volume discount pricing strategy and the composite strategy. For the convenience of the study, the following two cases were put together and compared with MATLAB.

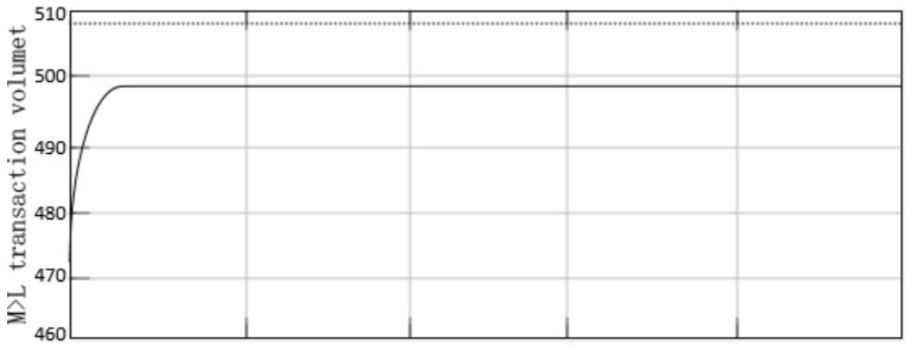

Figure. 7 The influence of risk weighting coefficient on AQDP & composite strategy

In order to analyze the difference between the volume discount pricing strategy and the compound strategy more clearly and intuitively, we reduce the value of the transaction volume to a smaller range for observation. In the case of random computer values, a separate volume discount pricing strategy appears. The transaction volume of the composite strategy will be slightly larger than the maximum value of 500 for the market demand, while the volume of the volume discount pricing strategy alone is larger than that of the composite strategy. In general, under any circumstances the combination of BI insurance and volume discount pricing strategies is the most favorable choice for the supply chain.

5. Conclusion

This paper studies BI insurance and volume discount pricing strategies and finds that when the market demand surges, the combination of BI insurance and volume discount pricing strategies will be more in line with the demand expectations of the supply chain, which can increase the transaction volume and Controlling the volume of transactions within a certain range is not too large and exceeds market demand, thus avoiding waste of resources and improving research on prevention of supply chain disruption and supply chain coordination.

However, there are some shortcomings in this paper. Firstly, whether the composite strategy of combining BI insurance and supply chain interruption can be applied in the case of reduced demand requires further research. Secondly, the profit sensitivity coefficient of each node in the supply chain under the two strategies when the impact is consistent, how to choose the optimal strategy is also a problem worthy of weighing.

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