Cordination of VMI Supply Chain on the Base of Loss Aversion and Replenishment

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Abstract: Numerous studies have demonstrated that implementing replenishment strategies can reduce shortage costs, and the presence of loss-averse behavior can also impact decision-making within enterprises. Both the choice of replenishment strategy and the manifestation of loss-averse behavior ultimately influence the level of coordination within supply chains. Replenishment strategy has been overlooked in most existing studies on supply chain coordination with loss aversion. This paper, however, employs the psychological account separation method to depict the loss-averse behavior of a supplier in a two-level Vendor Managed Inventory (VMI) supply chain, consisting of a loss-averse supplier and a risk-neutral retailer. To investigate the impact of supplier's loss aversion behavior on supply chain coordination, this study constructs supply chain coordination models under risk diversification contract, option contract and subsidy contract respectively. The research indicates that the aforementioned three types of coordination contracts are capable of driving the supply chain towards a state of coordination and achieving Pareto improvement. In comparison to option and subsidy contracts, suppliers show a greater preference for risk diversification contracts. If the supplier exhibits a high degree of loss aversion, option contracts and subsidy contracts will not be utilized for supply chain coordination. The findings contribute to the enhancement of VMI supply chain coordination management methods.

Keywords: Supply Chain Management; Loss Aversion; Replenishment Strategy; Coordinating Contracts.

1. Introduction

Recent studies have increasingly focused on the application of advanced models in supply chain coordination, particularly under loss aversion contexts. For example, Zhang et al. (2023) explored mechanisms within multi-echelon supply chains, addressing dynamic market demands and complex decision frameworks. Liu and Fan (2022) further analyzed multi-layered strategies under uncertain markets, providing essential insights for this study's positioning.

Vendor Managed Inventory (VMI) fosters collaboration and integration among all stakeholders in the supply chain.[1] This approach is predominantly utilized within the retail sector, as exemplified by its successful implementation at Procter & Gamble (P&G) and Wal-Mart in the United States.[2] Subsequently, an increasing number of scholars have conducted comprehensive studies on this model from various perspectives, including consignment inventory agreements,[3] game theory applications,[4] information sharing mechanisms,[5] and so forth. In order to mitigate the impact of insufficient inventory, suppliers often make replenishment decisions. For instance, Yang and Qing [6] utilized the dynamic programming method to explore the multi-phase dynamic replenishment strategy under VMI. Zhang and Wei [7] illustrated that the distributed inventory system based on VMI and hierarchical distributed dynamic inventory management strategy can facilitate replenishment. CAI [8] emphasized that substitution effect and replenishment cost can significantly influence

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replenishment decisions, which in turn can substantially enhance profits for both suppliers and retailers. These studies undoubtedly shed light on a promising path for the VMI model with a replenishment strategy. However, these studies presuppose that the decision makers in the supply chain are risk-neutral, a premise which may not entirely align with the actual market environment. Indeed, as highlighted by Nobel Prize laureate Richard Thaler, individuals exhibit bounded rationality and their loss aversion preferences can significantly impact decision-making behaviors,[9] as evidenced in financial and inventory management strategies.[10]

Loss aversion, as a prototypical manifestation of psychological preference, denotes the phenomenon wherein decision makers exhibit greater reluctance to accept losses compared to equivalent gains. An increasing number of scholars have examined the phenomenon of loss aversion from various perspectives, including the newsboy model with recourse,[11] dual-channel ordering [12], product pricing,[13] game problems involving uncertain production and demand [14] and so on. The aforementioned studies all employed the method of piecewise linear value function, leading to relatively intricate findings. As a result, some scholars have opted for simpler approaches, such as the method of multiple mental account separation.[15，16] While these studies have made valuable contributions to the further exploration of loss aversion, it is important to note that the overall efficiency of the supply chain has not been taken into consideration

The application of supply chain contracts has been instrumental in enhancing overall operational efficiency. Within the VMI supply chain, various significant achievements have been realized, such as the diversification contract for risk sharing and unilateral compensation,[17] the option contract widely utilized in fashion, electronics, and fast-moving consumer goods industries,[18] and the subsidy contract commonly employed in the mobile phone industry.[19] These contracts not only facilitate coordination within the supply chain but also effectively promote collaboration among its members. This paper delves deeper into an extensive exploration of these contracts. Referred from the extant literature, it is evident that there is a dearth of research on the consideration of supplier's loss aversion in VMI supply chain coordination.

While Liu et al [20-22] have designed a VMI supply chain coordination mechanism from a loss aversion perspective, their studies did not include the replenishment strategy. On the other hand, Cai et al [23，24] considered VMI supply chain coordination under the replenishment strategy but did not take into account the impact of loss aversion. In such context, this paper will explore a two-level VMI supply chain with a replenishment strategy and determine optimal production under loss aversion using the mental account separation method. Additionally, we will verify the coordination functions of risk-sharing contracts, option contracts, and subsidy contracts while discussing the differences among these three contract types.

2. Basic Model

To ensure clarity in mathematical derivations, all symbols have been standardized, and detailed explanations have been added to key steps. For example, in the derivation of Equation (4), the distinctions between supplier revenues and costs are explicitly articulated, particularly regarding the impacts of overproduction and replenishment strategies.

2.1 Problem Description and Underlying Assumption

In a two-tier VMI supply chain, comprising of a sole supplier and a single retailer, the retailer exhibits risk neutrality while the supplier demonstrates loss aversion. The market demand x is subject to uncertainty, but it conforms to the cumulative distribution function $F(x)$ and the probability distribution function $f(x)$. In general, $F(\cdot)$ exhibits continuous monotonic increase with ·, and $F(0)=0$. Given a known production cost c, the supplier determines its output Q and sells products to retailers at a unit wholesale price w. Assuming the unit retail price is p, each unit of excess product holds a residual value v when the output exceeds market demand after the sales season. In cases where the output falls short of market demand, the supplier implements a replenishment strategy to meet unsatisfied demand. At this point, the unit replenishment cost is c_1, and the wholesale price for each additional product $(x-Q)^+$ is w_1.

In general, assuming $p>w>c>t>0$, the supplier must ensure timely production and shipment of products to the retailer for replenishment. Therefore, $c_1 \geq c$, leading to an increase in the wholesale price provided by the supplier to the retailer ($w_1 \geq w$). Furthermore, assuming $w-c \geq w_1-c_1$, otherwise suppliers in a pull supply chain will only produce based on actual demand during sales seasons.[23]

Write π as the expected profit, where subscript s and r represent the supplier and retailer respectively, and superscript I, RC, OC, SS stand for centralized decision making, risk diversification contract, option contract, and subsidy contract respectively.

The loss avoidance attitude of suppliers is described using the psychological account separation method, and the specific utility function can be found in the works of Gu Bojun and Zhang Xiang.[25]

$$G(x)=-\mathcal{V}(x)^- +(x)^+ \quad (1)$$

In this function $(x)^- =-min\{x, 0\}$, $(x)^+=max\{x, 0\}$. $\vartheta \geq 1$ stands for degree of loss aversion, $\vartheta = 1$ stands for neutral risk.

2.2 Decision Making Analysis

The following section is dedicated to the examination of two fundamental supply chain models: the centralized supply chain and the wholesale price contract model. Here, $S(Q)$ represents the sales volume of Q, which is defined as $S(Q) =E [min \{Q, x\}]$.

Under centralized decision-making, retailers and suppliers are integrated into the same organizational decision-making structure, thereby the overall objective function of the supply chain is:

$$\pi^I=pS(Q) +vE[(Q-x)^+]+(p-c_1)E[(x-Q)^+]-cQ \quad (2)$$

$\frac{\partial^2\pi^1}{\partial Q^2}=-(c_1-v)f(Q) <0$, thus π^I is strictly convex function to Q. The optimal strategy of supply chain is satisfied:

$$Q^{I*}=F^{-1}\left(\frac{c_1-c}{c_{1-v}}\right)$$

Under distributed decision-making, considering the wholesale price contract model, the expected profit of supplier and retailer is:

$$\pi_r=(p-w)S(Q)+(p-w_1)E[(x-Q)^+] \quad (3)$$

$$\pi_s=wS(Q)+(w_1-c_1)E[(x-Q)^+]+vE[(Q-x)^+]-cQ=(w-c)Q+(w_1-c_1)E[(x-Q)^+]-(w-v)E[(Q-x)^+] \quad (4)$$

$(w-v)\ E[(Q-x)^+]$ means the amount of loss when the supplier overproduces.

Since the supplier is loss-averse, formula (4) can be modified as following according to the principle of separating psychological accounts of revenue and cost:

$\pi_s= R_1(Q) - L_1(Q)$

$R_1(Q)=(w-c)S(Q)\ (w_1-c_1)+E[(x-Q)^+]$ is the revenue of suppliers.

$L_1(Q)=(c-v)\ E[(Q-x)^+]$ is the cost of overproduction.

Therefore, according to formula (1), there is:

$$G_s=\begin{cases}(w-c)Q-(w_1-c_1)(x-Q),\ Q\leq x\\(w-c)x-\mathcal{V}(c-v)(Q-x),\ Q>x\end{cases}$$

$=R_1(Q) - vL_1(Q)$

Since $\frac{\partial^2 G_s}{\partial Q^2}=-[(w-c)-(w_1-c_1)+\mathcal{V}(c-v)]f(Q)<0$, G_s is a strictly convex function of Q. Therefore, the optimal strategy of supply chain is satisfied:

$$Q^*=F^{-1}\left(\frac{W-C-W_1+C_1}{W-C-W_1+C_1+\mathcal{V}(C-V)}\right)$$

Since $\frac{c_1-c}{c_1-v}-\frac{w-c-w_1+c_1}{w-c-w_1+c_1+\mathcal{V}(c-v)}$

$$=\frac{\{\mathcal{V}(c_1-c)-[w-c-(w_1-c_1)]\}(c-v)}{[w-c-(w_1-c_1)+\mathcal{V}(c-v)](c_1-v)}$$

$$\geq\frac{(w_1-w)(c-v)}{[[w-c-(w_1-c_1)+\mathcal{V}(c-v)](c_1-c)]}>0$$

Because of the strict monoincrement of F, $Q^* < Q^{I*}$. That is to say, the output of suppliers cannot achieve centralized decision-making under the wholesale price contract.

3. Supply Chain Coordination

The section discusses three contract models: risk diversification contracts, option contracts, and subsidy contracts. It compares their advantages and disadvantages. In these types of contracts, the parameters are determined by suppliers, who assess the feasibility of these contracts based on supply chain coordination and Pareto improvement.

3.1 Risk Diversification Contract

Under the risk diversification contract (λ, T), the retailer will bear λ ($\lambda \in [0, 1]$) times the loss caused by the mismatch between supply and demand to the supplier, while the supplier will give the retailer T compensation. T may be negative, in which case, it indicates that the retailer will provide further fund to the supplier.

It is worth noting that in risk diversification contract, not only loss sharing but also side payment is considered, such as the risk diversification contract under capacity investment.[17] In contrast, the risk sharing contract only considers loss sharing. Therefore, it can be concluded that the risk diversification contract represents an advancement from the risk sharing contract. Therefore, the concept of risk diversification contract differs from that of a risk sharing contract. The former represents an advancement of the latter.

Under risk diversification contract, the expected profit of retailer and supplier can be satisfied respectively:

$$\pi_r^{RC} = (p-w)\, S(Q)+(p-w_1)\, E[(x-Q)^+] - (1-\lambda)(w-v)\, E[(Q-x)^+] + T \quad (5)$$

$$\pi_s^{RC} = (w-c)\, Q+(w_1-c_1)\, E[(x-Q)^+] - \lambda(w-v)\, E[(Q-x)^+] - T \quad (6)$$

As the supplier is loss-averse, formula (6) can be further divided into revenue and cost as following:

$$\pi_s^{RC} = R_2(Q) - L_2(Q)$$

In which $R_2(Q)=(w-c)\ S(Q)+(w_1-c_1)\ E[(x-Q)^+]-T$ represents revenue, $L_2(Q) =\lambda(w-v)-(w-c)]\ E[(Q-X)^+]$ represents overproduction cost. Obviously, $\lambda > \frac{w-c}{w-v}$, or cost will be negative. Therefore, according to formula (1) the loss avoidance utility function of supplier is satisfied:

$$G_s^{RC}=R_2(Q) - \mathcal{V}\ L_2(Q)$$

Because $\frac{\partial^2 G_s^{RC}}{\partial Q^2} = -[w-c-(w_1-c_1)]\ f(Q) - \mathcal{V}[\lambda(w-v) -(w-c)]\ f(Q)<0$, G_s^{RC} is a strictly convex function of Q and the optimal strategy under the risk diversification contract is satisfied:

$$Q^{RC*} = F^{-1}\left(\frac{w-c-w_1+c_1}{(1-\mathcal{V})(w-c)-w_1+c_1+\mathcal{V}\lambda(w-v)}\right)$$

Theorem 1 Risk diversification contract can achieve supply chain coordination and Pareto improvement, and meet the following conditions:

$$\lambda^*=\frac{w-c}{w-v} + \frac{(w-c-w_1+c_1)(c-v)}{\mathcal{V}(w-v)(c_1-c)},\ \ T \in [\underline{T}, \overline{T}]$$

In this formula

$$\begin{cases} \underline{T} = \pi_r(Q^*) - \pi_r(Q^{I^*}) + (1-\lambda^*)(w-v)E[(Q^{I*}-x)^+] \\ \overline{T} = G_s(Q^{I*}) - G_s(Q^*) + \mathcal{V}(1-\lambda^*)(w-v)E[(Q^{I*}-x)^+] \end{cases}$$

Theorem 1 suggests that: 1) Suppliers can enhance the performance of supply chain members by adjusting the allocation of loss sharing and side payments, thereby achieving supply chain coordination; 2) To achieve supply chain coordination, suppliers should decrease the proportion of loss sharing as loss avoidance increases.

3.2 Option Contract

According to the option contract, the retailer acquires Q options from the supplier at the unit option price k and pays for the actual volume $S(Q)$ at the unit option strike price o. It is generally assumed that $c-v> k>0$; otherwise, the supplier would generate an infinite positive profit from the products.[23]

Simultaneously, $o>v$, otherwise the supplier will not fulfill product orders during the selling season. Consequently, the anticipated profits of both the retailer and supplier through the option contract can be achieved respectively as following:

$$\pi_r^{OC}=(p-o)\ S(Q)+(p-w_1)\ E[(x-Q)^+]-kQ \quad (7)$$

$$\pi_r^{OC}=oS(Q) +(w_1-c_1)\ E[(x-Q)^+]-cQ +kQ +vE[(Q-x)^+] \quad (8)$$

Cut supplier's expected profit into revenue and cost, there is:

$$\pi_s^{OC}=R_3(Q) - L_3(Q)$$

In this formula, $R_3(Q) = (o-c)\ S(Q) +(w_1- c_1)\ E\ [(x- Q)^+] +kQ$ stands for revenue, $L_3(Q) = (c-v)\ E\ [(Q- x)^+]$ stands for overproduction cost.

Therefore, according to formula (1), the supplier's loss aversion utility function is:

$$G_s^{OC}=R_3(Q) - \mathcal{V}L_3(Q)$$

Because $c-v>k>0$, then $o-c-(w_1-c_1)+ \mathcal{V}(c-v)>o+k-c-(w_1-c_1)$.

Under the replenishment strategy of supplier, there is $o+k-c\geq w_1-c_1$. Otherwise, the supplier under the pull supply chain will only produce actual demand in the sales season. Therefore, $\frac{\partial^2 G_s^{OC}}{\partial Q^2} = -[o-c-(w_1-c_2) +\mathcal{V}(c-v)]f(Q)<0$, G_s^{OC} is the strictly convex function of Q and the optimal policy is satisfied with:

$$Q^{OC*}=F^{-1}\left(\frac{o-c+k-w_1+c_1}{o-c-w_1+c_1+V(c-v)}\right)$$

Theorem 2 Option diversification contract can achieve supply chain coordination and Pareto improvement, and meet the following conditions:

$$k^*=\frac{(c-v)[\mathcal{V}(c_1-c)-o+c+w_1-c_1]}{c_1-v},\ \ \mathcal{V} \in (\underline{\mathcal{V}}, \overline{\mathcal{V}}),\ \ o\in [\underline{o}, \overline{o}]$$

In this formula, there is:

$$\begin{cases} \underline{\mathcal{V}} = min\left\{1+\frac{\pi^I(Q^*)-\pi^I(Q^{I^*})}{(c-v)\int_{Q^{I*}}^{Q^*} F(x)dx}, 1+\frac{o-v-w_1-c_1}{(c_1-c)}\right\} \\ \overline{\mathcal{V}} = max\left\{1+\frac{o-w_1}{c_1-c}, 1\right\} \end{cases}$$

$$\begin{cases} \underline{o} = \frac{G_s(Q^*) - G_S(Q^{I^*}) - k^*Q^{I^*}}{S(Q^{1*})} + w \\ \overline{o} = \frac{\pi_r(Q^{I^*}) - \pi_r(Q^*) - k^*Q^{I^*}}{S(Q^{I^*})} + w \end{cases}$$

Theorem 2 suggests that: 1) The supplier can enhance the performance of supply chain members by adjusting the option price to achieve coordination within the supply chain;

2) To achieve coordination in the supply chain, the supplier should increase the option price as loss aversion increases; 3) If the supplier's degree of loss aversion is too high, the option contract will not be effective in coordinating the supply chain.

3.3 Subsidy Contract

According to the subsidy contract, the retailer purchases the product at price w^{ss} and subsidizes the surplus output of the supplier at a unit subsidized price of b. As a result, the anticipated profits of both the retailer and supplier under the subsidy contract can be met as following:

$$\pi_r^{SS} = (p - w^{ss})\, S(Q) + (p - w_1) \cdot E[(x-Q)^+] - bE[(Q-x)^+] \tag{9}$$

$$\pi_s^{SS} = w^{SS}(Q) + (w_1 - c_1)\, E[(x-Q)^+] - cQ + (b+v)\, E[(Q-x)^+] \tag{10}$$

Cut supplier's expected profit into revenue and cost, there is:

$$\pi_s^{SS} = R_4(Q) - L_4(Q)$$

In this formula, $R_4(Q)=(w^{SS}-c)\ S(Q)+(w_1-c_1)\ E[(x-Q)^+]$ stands for revenue, $L_4(Q)=(c-b-v)\ E[(Q-x)^+]$ stands for overproduction cost. Obviously, $b<c-v$, or the cost will be negative.
Therefore, according to formula (1), the supplier's loss avoidance utility function is:

$$G_s^{SS} = R_4(Q) - \mathcal{V} L_4(Q)$$

Because $b<c-v$, then $w^{SS}-c-w_1+c_1+\mathcal{V}(c-b-v) > w^{SS}-c-(w_1-c_1)$.

Under the replenishment strategy of supplier, there is $w^{ss}-c \geq w_1-c_1$. Otherwise, the supplier under the pull supply chain will only produce actual demand in the sales season. Therefore, $\frac{\partial^2 G_s^{SS}}{\partial Q^2} = -[w^{SS}-c-w_1+c_1+\mathcal{V}(c-b-v)], f(Q)<0$. G_s^{SS} is the strictly convex function of Q and the optimal policy is satisfied with:

$$Q^{ss^*} = F^{-1}\left(\frac{w^{ss} - c - w_1 + c_1}{w^{ss} - c - w_1 + c_1 + \mathcal{V}(c - b - v)}\right)$$

Theorem 3 Subsidy contract can achieve supply chain coordination and Pareto improvement, and meet the following conditions:

$$b^* = (c - v)\left(1 - \frac{w^{ss} - c - w_1 + c_1}{\mathcal{V}(c_1 - c)}\right),$$

$$w^{ss} \in \left[\underline{w}^{ss}, \overline{w}^{ss}\right],\ \mathcal{V} < 1 + \frac{\pi^I(Q^{I^*}) - \pi^I(Q^*)}{(c - b^* - v)\int_{Q^{1^*}}^{Q^*} F(x)dx}$$

In this formula, there is:

$$\begin{cases} \underline{w}^{ss} = \dfrac{G_s(Q^*) - G_s(Q^{I^*}) - b^* \mathcal{V} E[(Q^{I^*} - x)^+]}{S(Q^{1^*})} + w \\ \overline{w}^{ss} = \dfrac{\pi_r(Q^{I^*}) - \pi_r(Q^*) - b^* E[(Q^{I^*} - x)^+]}{S(Q^{I^*})} + w \end{cases}$$

Theorem 3 suggests that: 1) The supplier can enhance the performance of supply chain members by adjusting the subsidy price to achieve coordination within the supply chain; 2) To achieve coordination in the supply chain, the supplier should increase the subsidy price as loss aversion increases; 3) If the supplier's degree of loss aversion is too high, a subsidy contract will not be effective in coordinating the supply chain.

3.4 Comparative Analysis of Contract

The above analysis illustrates that risk diversification contracts, option contracts, and subsidy contracts have the potential to improve the efficiency of supply chains. However, it is crucial to determine which contract offers the greatest benefits. Therefore, a comparison between risk diversification contracts and the other two types is conducted in the following section.
Theorem 4 In a VMI supply chain with a single loss-averse supplier and a single risk-neutral retailer, the risk diversification contract is more preferable than the option contract and subsidy contract.
Theorem 4 indicates that in the context of supply chain coordination, the performance of both parties is higher under a risk diversification contract compared to the other two contracts. This suggests that both parties are more inclined to adopt a risk diversification contract in order to avoid losses.

4. Numerical Experiments

To enhance the robustness of the results, additional numerical experiments have been conducted. These include analyzing different market demand distributions, such as normal and exponential distributions, as well as varying cost structures encompassing production, transportation, and inventory costs. The extended analysis demonstrates significant impacts on supply chain coordination strategies, further validating the study's conclusions.
This paper conducts relevant numerical experiments to demonstrate the impact of loss aversion on Pareto improvement in risk diversification contracts, option contracts, and subsidy contracts.
Assuming p=15， w_1=11, w=10, c_1=7， c=5， v=2, market demand x follows a uniform

distribution from [0, 200]. In order to ensure profit, then o>2，k>9-o, w^{ss} >9.

Figure 1 illustrates that the scope of side payment will expand as the supplier's degree of loss aversion increases under a risk diversification contract. This indicates that in order for both parties to achieve profitability, the supplier will broaden the proposed scope of side payment as their level of loss aversion rises.

Figure 1 illustrates how the degree of loss aversion influences the Pareto improvement scope under a risk-sharing contract. As the loss aversion degree increases, the supplier needs to expand the payment scope to achieve balanced profitability, a trend depicted as a linear expansion in the figure.

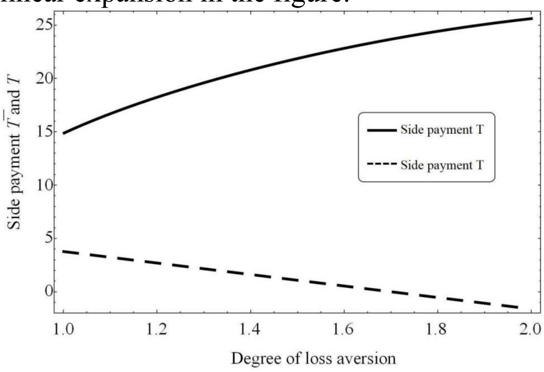

Figure 1. The Influence of Loss Aversion Degree On Pareto Improvement of Risk Diversification Contract

Figure 2 illustrates that, under an option contract, the supplier will decrease the strike price as the level of loss aversion increases. Additionally, the range of the option strike price diminishes with an increase in the supplier's degree of loss aversion. This implies that, in order to achieve profitability, the supplier will narrow down the proposed range of the option strike price as their degree of loss aversion increases.

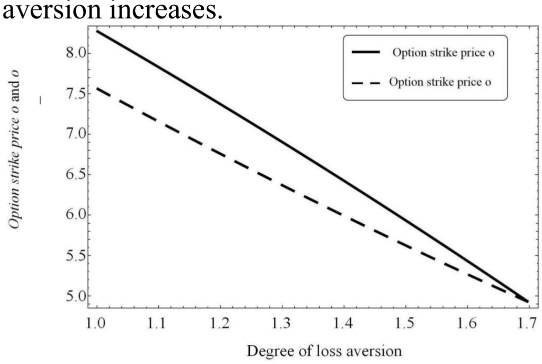

Figure 2. The Influence of Loss Aversion Degree on Pareto Improvement of Option Contract

Figure 3 illustrates that, under a subsidy contract, the supplier will increase the wholesale price as the degree of loss avoidance rises. Additionally, the range of wholesale prices that allows both parties to profit decreases as the supplier's loss aversion degree increases. This implies that, in order for both parties to achieve profitability, the supplier will narrow down the proposed range of wholesale prices with an increasing level of loss aversion.

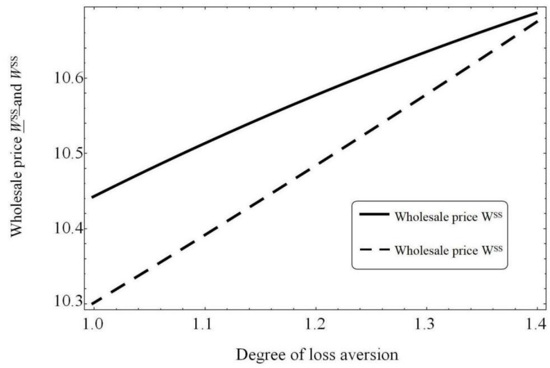

Figure 3. The Influence of Loss Aversion Degree on Pareto Improvement of Subsidy Contract

To conclude, the extent of suppliers' loss aversion not only impacts parameter configuration, but also influences the applicability of each contract. Therefore, in today's increasingly intricate trading landscape, it is advisable for suppliers and retailers to consider implementing risk diversification contracts in order to achieve enhanced profitability.

5. Conclusion

The findings of this study hold practical implications for real-world supply chain management. For instance, implementing risk-sharing contracts may require careful consideration of the behavioral preferences and cost-sharing capabilities of suppliers and retailers. Additionally, the execution of option and subsidy contracts may encounter challenges related to implementation costs and contract design complexity.

It is important to note that this study assumes a single supplier and a single retailer in the supply chain, which simplifies the analysis but may not fully reflect the complexity of real-world markets. Future research could extend this model to multi-supplier and multi-retailer contexts to enhance its applicability.

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In conclusion, suppliers control over inventory in the VMI mode. This paper examines the optimal inventory management of suppliers in a two-level VMI supply chain, comprising a single loss-averse supplier and a single risk-neutral retailer. To mitigate losses resulting from insufficient output, suppliers adopt replenishment strategies and utilize the psychological account separation method to characterize loss aversion. Retailers employ contracts to incentivize production, thereby enhancing overall operational efficiency of the supply chain. The primary contributions are as follows:

Firstly, we establish supply chain coordination models under risk diversification contract, option contract, and subsidy contract respectively. Our research demonstrates that these three contracts are capable of coordinating the supply chain and achieving Pareto improvement. In other words, from the perspective of risk sharing, both sides of the supply chain can incentivize suppliers to produce by adopting risk diversification contract, option contract, and subsidy contract in order to enhance overall operational efficiency and achieve long-term cooperation.

Secondly, upon comparing and analyzing the aforementioned three types of contracts, it is evident that the performance under a risk diversification contract surpasses that of the other contracts. In essence, suppliers exhibit a greater inclination towards adopting risk diversification contracts to effectively coordinate supply chains.

Finally, this paper has unveiled the impact of varying degrees of loss aversion on Pareto improvement across the aforementioned three contract types. When the degree of loss aversion is excessively high, suppliers are less likely to opt for option contracts or subsidy contracts.

However, the model presented in this paper is relatively ideal as it only considers the "one-to-one" situation. Future studies will delve into discussing VMI supply chain coordination under a replenishment strategy involving multiple suppliers. Additionally, this paper solely focuses on VMI supply chain based on replenishment strategy and loss aversion behavior, without taking into account the promotional efforts of transaction participants. Therefore, future research will also consider VMI supply chain coordination under sales efforts and replenishment strategies.

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