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Research on Direct Supply Chain Decisions Based on Regret Behavior

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ABSTRACT
Against the backdrop of the rise of the direct sales model, manufacturers not only undertake production functions but also sell directly to consumers. This makes the impact of consumer behavioral factors, particularly anticipated regret behavior, on operational decisions increasingly prominent. Focusing on manufacturers that sell short-life-cycle products through direct sales channels, this study introduces consumers' anticipated regret behavior within the framework of the newsvendor model, and constructs a supply chain decision-making model in the direct sales environment. The research considers two types of consumer regret behavior—regret from high prices and regret from stockouts. By establishing a structured demand function and conducting optimization calculations, it analyzes the mechanism through which regret behavior affects manufacturers' optimal pricing, production quantity decisions, and profit performance. The findings indicate that: Consumers' regret behavior significantly reduces manufacturers' optimal production quantity, and this impact strengthens as demand uncertainty increases; There is an inverted U-shaped relationship between the optimal price and regret sensitivity, where the optimal price first rises and then falls as regret sensitivity changes; Moderate regret behavior may improve manufacturers' profits, but excessively high regret sensitivity will impair their performance. The results of this study reveal the differences in the impacts of different types of regret, provide management implications for direct sales enterprises in areas such as dynamic pricing and inventory optimization, and offer a theoretical basis for behavior-oriented supply chain decision-making.

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I. INTRODUCTION

The core of supply-chain management is to achieve an efficient allocation of resources under uncertainty through a set of coordinated decisions. Joint optimization of pricing and production/inventory decisions has long been a focal topic in operations management. The classic newsvendor model and its extensions provide a fundamental analytical framework for single-period decision making under demand uncertainty. Traditional models, however, usually assume that the decision maker is perfectly rational and aims to maximize expected profit or expected utility, and that market demand is an exogenous variable influenced only by objective factors such as price. These assumptions largely ignore systematic influences of behavioral factors—especially regret—on the outcomes of the decision process.

With the deep penetration of the "Internet +" model and the growing maturity of e-commerce infrastructure, a direct-sales channel has become a pivotal route for manufacturers' strategic transformation. Well-known firms worldwide—Apple, Dell, and Tesla abroad, and Haier, Xiaomi, and Midea in China—have all built official online stores and company-owned experience shops to reach end-consumers directly. By eliminating intermediary distributors, the model theoretically grants manufacturers wider margins and tighter market control. Yet it also forces them to perform both production and sales functions and to confront the far more complex behavioral uncertainty that originates at the consumer level. In a direct-sales setting, consumers do not base purchase decisions solely on a simple value-price comparison; their choices are heavily shaped by psychological expectations and emotional factors, among which anticipated regret is a ubiquitous and particularly influential behavioral driver. Relevant research (Nasiry & Popescu, 2012; Jiang et al., 2017) has pointed out that expected regret can affect consumers' decision-making and retailers' pricing, pre-sale strategies, competitive strategies, and product innovation.

Loomes & Sugden (1982) pointed that, anticipated regret is the psychological process in which individuals foresee that their current choice may cause them to feel regret in the future. In a direct-sales context, consumers face two typical regret risks: (a)High-price regret: the fear that the product will soon be discounted after purchase, inflicting a monetary loss. (b)Stock-out regret: the fear that the desired item will sell out while they hesitate, causing them to miss the opportunity altogether (Nasiry & Popescu, 2011). Real-world illustrations abound: the wave of Surface Pro 4 returns to Microsoft shortly after its launch when prices were quickly reduced, and the consumer backlash and lost market share that follow hot new products—flagship smartphones, limited-edition items—when inventory proves insufficient. Such forward-looking regret expectations materially alter consumers' willingness to pay and the timing of their purchases, thereby reshaping the effective demand curve that the manufacturer confronts.

This paper studies a manufacturer that sells a short-life-cycle product through a single direct channel and casts its decision problem within the newsvendor framework. We aim to answer the following research questions:

(1)How can a demand model be constructed that simultaneously captures consumers' high-price regret and stock-out regret?

(2)When these regret effects are present, what are the manufacturer's optimal price and production quantity, and how do they fundamentally differ from the solutions of the classical model?

(3)How do consumers' regret-sensitivity parameters influence the optimal decisions and, ultimately, the manufacturer's profit?

(4)What are the different mechanisms through which high-price regret and stock-out regret affect supply-chain decisions, and what targeted measures should managers take in response?

To address these questions, we incorporate anticipated-regret theory into the newsvendor setting and build a Stackelberg game in which the manufacturer acts as leader and the consumer population as follower. Using backward induction we derive closed-form conditions for the optimal price and quantity, and then conduct numerical experiments and sensitivity analyses to uncover how regret behavior alters the decisions and their performance outcomes.

II. LITERATURE REVIEW

This study is anchored in three inter-related streams of literature: regret theory in behavioral operations management, consumer-behavior research in supply-chain settings, and analytical models of direct-sales supply chains. The following review systematically maps these areas to clarify the paper's theoretical foundations and positioning.

Phase I: Regret Theory in Behavioral Operations Management

Traditional operations models universally rest on the "perfectly rational economic agent" assumption. Behavioral operations management enriches explanatory power by incorporating cognitive biases and emotional factors. Regret theory—an influential branch of behavioral economics—has become one of the discipline's central pillars.

The core ideas were formalized by Bell (1982) and Loomes & Sugden (1982), who introduced regret (and rejoicing) as utility-relevant comparisons between chosen and foregone alternatives. Pieters & Zeelenberg (2008) later distinguished "experienced regret" from "anticipated regret," showing that the latter—regret foreseen before a decision—is more immediate and potent in shaping risky choices.

Within operations, regret research has evolved along two dimensions:

Decision-maker regret examines how managers' (retailers', manufacturers') regret-averse preferences distort ordering, pricing, or capacity decisions. Schweitzer & Cachon's (2000) seminal experiment, for example, documented systematic deviations from newsvendor-optimal quantities, revealing asymmetric disutility for leftover inventory versus lost sales.

Consumer regret focuses on how buyers' anticipated regret alters purchase behavior and, thereby, the demand pattern firms ultimately face. This second dimension is the focal concern of the present paper.

Phase II: Consumer Regret in Supply-Chain Research

Incorporating consumer regret into supply-chain models has become an active sub-field over the past decade. The literature can be grouped by the type of regret modeled and by supply-chain structure, yielding markedly different emphases.

Price- and quality-driven regret. Early work concentrates on regret that arises after purchase when consumers observe a lower price or a superior product. Nasiry & Popescu (2011) is the seminal paper: they build a dynamic pricing model in which buyers anticipate future markdowns ("high-price regret") and therefore delay purchases. The resulting strategic waiting forces the firm to adopt a high–low pricing path instead of a constant price. Jiang et al. (2016) extend the framework to simultaneous regret over both price and quality, examining how these emotions affect the retailer's return policy and pricing strategy. They uncover a non-monotonic relationship between regret sensitivity and optimal price—a finding that informs our own analysis. Guo et al. (2023) introduce a setting where a firm can stochastically combine existing products into new ones at zero development cost. They show how anticipated regret shapes the design, pricing, and selling strategy of such "synthetic" products, and demonstrate that both firm and consumers can benefit from the presence of regret.

Inventory- and stockout-driven regret. A second strand focuses on the informational signal sent by inventory levels. Cachon & Swinney (2009, 2011) provide the landmark studies. High inventories signal low popularity or a high likelihood of future discounts, depressing current demand; low inventories may trigger "panic buying" but also cause lost sales when stockouts occur. The authors cast these forces in a regret framework: consumers trade off "purchase regret" (buying an unpopular or soon-to-be-discounted product) against "non-purchase regret" (missing the opportunity to acquire a desired item). Su & Zhang (2009) reach a complementary conclusion: in a rational-expectations equilibrium, strategic consumers infer the stockout probability from the firm's inventory level and adjust their purchase timing accordingly, making it essential for the firm to internalize this endogenous demand response when choosing inventory.

Phase III: Decision Models of Direct-Sales Supply Chains

Decision models for the direct-sales channel—as a distinct supply-chain structure—have been studied extensively. Early work focused on comparing a direct channel with a conventional retail channel, analyzing resulting channel conflict and coordination (Chiang et al., 2003); these models typically treated demand as exogenous or as a deterministic function of price.

As the literature evolved, behavioral elements were gradually introduced. For example, in dual-channel settings, researchers have examined how consumer preferences for one channel or free-riding behavior influence the manufacturer's pricing and channel strategies (Dan et al., 2012). However, consumer behavior is still usually represented by exogenous parameters; the underlying psychological mechanisms—such as regret—and their endogenous interaction with operational decisions (e.g., inventory) that ultimately shape demand have yet to be fully explored.

Overall, the extant literature is limited in three main respects:

Isolated decisions: most studies treat pricing and inventory/production choices separately, or focus on only one of them, leaving a systematic analysis of the manufacturer's joint decision-making under behavioral influences largely missing.

Single-context modeling: when regret is introduced, only one type—either price regret or stock-out signaling—is typically examined; the two coexisting and mutually reinforcing psychological mechanisms that shape consumer behavior in direct channels (high-price regret and stock-out regret) have not been integrated within a single framework.

Misaligned decision entity: research on inventory signaling usually adopts the downstream retailer as the focal agent, thereby overlooking the distinctive challenges of a direct-selling manufacturer who simultaneously faces production uncertainty (on the cost side) and market uncertainty (on the demand side).

This paper is intended to close these gaps. Its core innovation is to embed both high-price and stock-out regret into a joint pricing-and-quantity model for a direct-selling manufacturer within a newsvendor framework. Through rigorous modeling and optimization, we reveal how the two regret effects interact and collectively reshape the firm's optimal operational strategy and performance, offering new theoretical insights for behavior-oriented direct-sales supply-chain management.

III. MODEL CONSTRUCTION AND SOLUTION

This study considers a scenario where a manufacturer sells a single product through a direct sales channel. Acting as the decision-maker, the manufacturer undertakes both production and sales functions, and is required to determine the optimal production quantity Q and price p in an environment with uncertain demand. Consumer demand is affected by both price and regret behavior, and follows an additive form:

$$D(p) = a - bp + \varepsilon \tag{1}$$

where a represents the total potential market demand, $b > 0$ denotes the price sensitivity coefficient, and ε is a random disturbance term that follows a uniform distribution over the interval $[-\sigma, \sigma]$.

Consumers exhibit anticipated regret behavior in their purchase decisions: when the product is out of stock, consumers who did not purchase will experience stockout regret; when the price drops after purchase, consumers who bought the product will experience high-price regret. With reference to Loomes & Sugden (1982) and Nasiry & Popescu (2011), the utility of consumers with regret behavior when choosing to purchase is defined as:

$$U_c = v - p - \gamma\left(p - \underline{p}\right) - \gamma\rho(v - p) \tag{2}$$

where v denotes consumers' valuation of the product; γ represents the consumers' regret sensitivity coefficient, with $0 \leq \gamma \leq 1$; p stands for the lowest price that consumers expect to appear in the future; and ρ is the probability of stockout. Consumers will choose to purchase the product when $U_c \geq 0$.

Consumers' purchase decisions depend on the condition$U_c \geq 0$, while ρ (stockout probability) is an endogenous variable, which is determined by the total demand D and the manufacturer's production quantity Q. For the convenience of solving the model, it is assumed here that consumers are homogeneous—meaning they share the same product valuation and regret sensitivity coefficient—and are capable of forming rational expectations. Building on the research in Literatures, the demand is decomposed into a price-related component and an inventory-related component:

$$D(p,Q,\gamma)=\left(1-\gamma\frac{p-\underline{p}}{v-\underline{p}}\right)(a-bp)-\gamma\cdot\frac{v-p}{\sigma}\cdot\max\left(Q-a+bp,0\right) \tag{3}$$

Among the components, $\left(1-\gamma\frac{p-\underline{p}}{v-\underline{p}}\right)(a-bp)$ represents the high-price regret term. The ratio $\frac{p-\underline{p}}{v-\underline{p}}$ denotes the proportion of utility loss caused by high-price regret; γ amplifies this loss, reduces consumers' willingness to pay, and thus acts as a demand discount factor. $\gamma\cdot\frac{v-p}{\sigma}\cdot\max\left(Q-a+bp,0\right)$ represents the stockout regret term. Here, $\max\left(Q-a+bp,0\right)$ stands for the excess production quantity: the larger this value, the lower the stockout risk perceived by consumers, the weaker the stockout regret, and the smaller the suppression on demand.

The manufacturer makes decisions with the goal of maximizing expected profit, and its profit function is expressed as:

$$\pi(p,Q)=p\cdot E[\min(D(p,Q,\gamma),Q]-cQ \tag{4}$$

where c denotes the unit production cost of the product. The model is solved using the Karush-Kuhn-Tucker (KKT) conditions and the backward induction method. For a given price p, the optimal production quantity Q^*satisfies the following condition:

$$F\left(\frac{Q^*-a+bp}{1-\gamma\cdot\frac{v-\underline{p}}{(v-p)^2}}\right)=\frac{p-c}{p} \tag{5}$$

Substitute Q^* into the profit function and take the derivative with respect to price p to obtain the first-order condition:

$$\frac{\partial\pi}{\partial p}=p\cdot\frac{\partial E[\min(D(p,Q,\gamma),Q]}{\partial p}+E[\min(D(p,Q,\gamma),Q]-c\frac{\partial Q^*}{\partial p} \tag{6}$$

The selling price p^*can be calculated according to Equation (6).

IV. THE IMPACT OF REGRET BEHAVIOR

Based on the aforementioned model construction and solution, several key conclusions of this section can be drawn.

Conclusion 1: Consumers' regret behavior will reduce the optimal output chosen by manufacturers, and the degree of this impact will increase with the rise in demand uncertainty.

Proof: Let $\varphi(\gamma)=1-\gamma\cdot\frac{v-\underline{p}}{(v-p)^2}$. Taking the partial derivative of both sides of Equation (5) with respect to γ, we can obtain:

$$f(\cdot)\cdot\left[\frac{1}{\varphi}\frac{\partial Q^*}{\partial\gamma}-\frac{Q^*-a+bp}{\varphi^2}\frac{\partial\varphi}{\partial\gamma}\right]=0 \tag{7}$$

Since $\frac{\partial\varphi}{\partial\gamma}<0$，it can be derived that $\frac{\partial Q^*}{\partial\gamma}=\frac{Q^*-a+bp}{\varphi}\frac{\partial\varphi}{\partial\gamma}<0$。

Furthermore, $\frac{\partial^2Q^*}{\partial\gamma\partial\sigma}=\frac{\partial}{\partial\sigma}\left(\frac{Q^*-a+bp}{\varphi}\frac{\partial\varphi}{\partial\gamma}\right)<0$。

Therefore, as consumers' regret behavior increases, the optimal output decreases. Moreover, as demand uncertainty increases, the inhibitory effect of regret behavior on output becomes stronger.

Conclusion 2: As consumers' regret behavior increases, the optimal price chosen by manufacturers first rises and then falls.

Proof: From Equation (4), the first-order conditions for output and price can be obtained as follows:

$$F_1(p,Q,\gamma)=\frac{\partial\pi}{\partial Q}=p\cdot\frac{\partial E[\min(D(p,Q,\gamma),Q]}{\partial Q}-c=0 \tag{8}$$

$$F_2(p,Q,\gamma)=\frac{\partial\pi}{\partial p}=E[\min(D(p,Q,\gamma),Q]+p\cdot\frac{\partial E[\min(D(p,Q,\gamma),Q]}{\partial p}=0 \tag{9}$$

According to the Implicit Function Theorem, in the neighborhood of the optimal solution (p^*,Q^*), if the Jacobian matrix is non-singular, then

$$\begin{bmatrix}\frac{\partial p^*}{\partial\gamma}\\ \frac{\partial Q^*}{\partial\gamma}\end{bmatrix}=-J^{-1}\cdot\begin{bmatrix}\frac{\partial F_1}{\partial\gamma}\\ \frac{\partial F_2}{\partial\gamma}\end{bmatrix} \tag{10}$$

where the Jacobian matrix is given by:

$$J=\begin{bmatrix}\frac{\partial F_1}{\partial p} & \frac{\partial F_1}{\partial Q}\\ \frac{\partial F_2}{\partial p} & \frac{\partial F_2}{\partial Q}\end{bmatrix} \tag{11}$$

According to Cramer’s Rule, we have:

$$\frac{\partial p^*}{\partial \gamma} = -\frac{\begin{vmatrix} \frac{\partial F_1}{\partial \gamma} & \frac{\partial F_1}{\partial Q} \\ \frac{\partial F_2}{\partial \gamma} & \frac{\partial F_2}{\partial Q} \end{vmatrix}}{\det(J)} \tag{12}$$

Let the numerator in Equation (10) be denoted as N, i.e.,

$$N = \frac{\partial F_1}{\partial \gamma} \cdot \frac{\partial F_2}{\partial Q} - \frac{\partial F_2}{\partial \gamma} \cdot \frac{\partial F_1}{\partial Q} \tag{13}$$

Since $\frac{\partial F_1}{\partial Q} = p \cdot \frac{\partial^2 E[\min(D(p,Q,\gamma),Q]}{\partial Q^2} < 0$ (the profit function is concave in output), $\frac{\partial F_2}{\partial Q} = \frac{\partial E[\min(D(p,Q,\gamma),Q]}{\partial Q} + p \cdot \frac{\partial^2 E[\min(D(p,Q,\gamma),Q]}{\partial p \partial Q} < 0$（the cross effect of price on output is typically negative）, and $\frac{\partial F_2}{\partial \gamma} = \frac{\partial E[\min(D(p,Q,\gamma),Q]}{\partial \gamma} + p \cdot \frac{\partial^2 E[\min(D(p,Q,\gamma),Q]}{\partial p \partial \gamma} < 0$。

However, for $\frac{\partial F_1}{\partial \gamma} = p \cdot \frac{\partial^2 E[\min(D(p,Q,\gamma),Q]}{\partial Q \partial \gamma}$, When γ is small, the cost path dominates. The marginal revenue of increasing output rises, so $\frac{\partial F_1}{\partial \gamma} > 0$; When γ is large, the demand path dominates. The marginal revenue of increasing output falls, so $\frac{\partial F_1}{\partial \gamma} < 0$.

From Equation (13), it can be inferred that:

When γ is small, $N < 0$，and thus $\frac{\partial p^*}{\partial \gamma} > 0$; When γ is large, $N > 0$，and thus $\frac{\partial p^*}{\partial \gamma} < 0$.

Therefore, as consumers' regret behavior γ increases from a small to a large value, the price chosen by manufacturers first rises and then falls.

Conclusion 3: A moderate degree of consumers' regret behavior can increase manufacturers' profits, but excessive regret behavior will reduce manufacturers' profits.

Proof: By the Envelope Theorem, the derivative of the optimal profit with respect to γ is:

$$\frac{d\pi^*}{d\gamma} = p^* \cdot \frac{\partial E[\min(D,Q^*]}{\partial \gamma} + \frac{\partial p^*}{\partial \gamma} \cdot E[\min(D,Q^*] \tag{14}$$

In Equation (14), the first term on the right-hand side represents the demand suppression effect, and the second term represents the price premium effect.

Furthermore, $\frac{\partial E[\min(D,Q^*]}{\partial \gamma} = E\left[\frac{\partial D}{\partial \gamma} \cdot I_{D<Q^*}\right]$where $I_{D<Q^*}$ is an indicator function that equals 1 if $D < Q^*$ and 0 if $D > Q^*$.

From Equation (3), we have:

$$\frac{\partial D}{\partial \gamma} = -\frac{p^* - p}{v - p^*} \cdot (a - bp^*) - \frac{v - p^*}{\sigma} \cdot \max(a - bp^* - Q^*, 0) < 0$$

According to Conclusion 2: When γ is small, $\frac{\partial p^*}{\partial \gamma} > 0$, and this term plays a dominant role in determining the value of $\frac{d\pi^*}{d\gamma}$, leading to $\frac{d\pi^*}{d\gamma} > 0$; When γ is large, $\frac{\partial p^*}{\partial \gamma} < 0$, and the demand suppression effect becomes dominant, resulting in $\frac{d\pi^*}{d\gamma} < 0$.

Therefore, a moderate degree of consumers' regret behavior increases manufacturers' profits, while excessive regret behavior reduces manufacturers' profits.

V. CONCLUSIONS

This study incorporates consumers' anticipated regret behavior into the traditional newsvendor model, constructing a joint pricing and production decision model for manufacturers under the direct-selling mode, and systematically analyzes the impact of regret behavior on supply chain decisions. The main research conclusions are as follows:

First, consumers' regret behavior exerts a systematic impact on manufacturers' optimal decisions. Specifically, an increase in regret sensitivity prompts manufacturers to reduce output, and this inhibitory effect becomes more pronounced in environments with high demand uncertainty. Meanwhile, there exists a non-monotonic relationship between the optimal price and regret sensitivity: in the low-regret region, manufacturers can compensate for regret costs by moderately raising prices; in the high-regret region, however, the demand suppression effect dominates, forcing manufacturers to adopt price-cutting strategies.

Second, the impact of regret behavior on manufacturers' profits exhibits a threshold characteristic. When regret sensitivity is below the threshold, moderate regret behavior may increase profits through the price premium mechanism; once it exceeds this threshold, the demand suppression effect will dominate profit changes, leading to a significant decline in profits. This non-monotonic relationship highlights the importance of managing regret risks.

Finally, different types of regret behavior have distinct impact mechanisms. Regret over high prices primarily affects pricing decisions, while regret over stockouts mainly influences production decisions. This difference provides a theoretical basis for manufacturers to implement targeted management.

Based on the research conclusions, this study proposes the following management recommendations:

For markets with low regret sensitivity, manufacturers should adopt a moderate premium strategy, converting consumers' regret into a competitive advantage through price commitments and value communication. At the same time, they should establish a flexible production system to respond to demand changes.

For markets with high regret sensitivity, manufacturers need to implement aggressive discount strategies to stimulate demand and reduce stockout risks through inventory optimization. Additionally, a regret risk early warning system should be established to monitor real-time changes in market regret sensitivity.

For different types of regret, differentiated response strategies should be implemented. In markets dominated by regret over high prices, manufacturers should strengthen price stabilization mechanisms; in markets dominated by regret over stockouts, priority should be given to ensuring inventory levels. Moreover, product line design should be used to cover consumer groups with different regret sensitivities.

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