Journal of Information & Optimization Sciences
ISSN 0252-2667 (Print), ISSN 2169-0103 (Online)
Vol. 47 (2026), No. 6, pp. 2155–2164
DOI : 10.47974/JIOS-2004

Strategically scarce : Leveraging a dynamic newsvendor model for fast fashion

Hasan Arslan *
Seokjin Kim †
Department of Information Systems and Operations Management
Suffolk University
Boston
Massachusetts
U.S.A.

Abstract

This study extends the dynamic newsvendor model to fast fashion, integrating demand spillover and deliberate understocking to explore inventory scarcity's impact on demand. We demonstrate that strategic understocking can amplify consumer demand and enhance retailer profits, challenging conventional inventory practices. Through a novel model incorporating word-of-mouth and exclusivity effects, our analysis reveals optimal stocking strategies for sequential product launches. A numerical experiment validates that strategic scarcity can yield up to 36% profit increases, offering actionable insights for fast-fashion retailers navigating dynamic market trends.

Subject Classification: *Primary 90B05 Secondary 91B42, 91B24, 91A80.*

Keywords: *Dynamic newsvendor, Fast fashion, Inventory, Scarcity.*

1. Introduction

In the ever-evolving world of fast fashion, where consumer tastes are as transient as the trends they follow, retailers face the complex challenge of inventory management. The ability to make informed decisions on stock levels is not merely a logistical concern - it shapes consumer behavior, influences brand perception, and ultimately dictates profitability. In this paper, we study the nuanced interplay between inventory scarcity and customer response, using a dynamic newsvendor model tailored to the fast-fashion retailers. Our focus is on quantifying the optimal inventory levels that a fast-fashion retailer should maintain to maximize profits. Recent research has expanded the application of

* *E-mail:* **harslan@suffolk.edu (Corresponding Author)**
† *E-mail:* **kim@suffolk.edu**

newsvendor models in supply chain contexts, with [1] applying game theory to analyze strategic interactions between parties in the newsvendor supply chain model. Chen's work demonstrated how cooperative and non-cooperative game approaches can lead to different optimal stocking decisions and profit outcomes when considering information symmetry between manufacturers and buyers. Building upon these game-theoretic insights, our study specifically explores how strategic inventory decisions in a dynamic newsvendor setting can influence demand across sequential selling periods, particularly in the fast fashion context where scarcity can be leveraged as a strategic tool.

Our study reveals a counterintuitive strategy: deliberate understocking can serve as a catalyst for demand, energizing the market and fostering a sense of urgency among consumers. This phenomenon, often overshadowed by traditional inventory management practices, is brought to the forefront through rigorous analysis and empirical evidence. Through a comprehensive numerical experiment, we illustrate the tangible benefits of understocking, challenging the conventional wisdom that more availability leads to better outcomes. The paper progresses as follows: Section 2 offers an examination of the existing literature, situating our work within the broader discourse on fast-fashion retailing and inventory models. Section 3 presents our dynamic newsvendor model, which captures the demand spillover effect — a pivotal factor in understanding the implications of inventory scarcity. In conclusion, we synthesize our primary insights and propose promising avenues for future research.

2. Literature review

The synergy between fast fashion and inventory management has increasingly engaged scholars, particularly given the rising demand for timely and affordable fashion. [2] emphasized the critical need for inventory strategies that are responsive to market trends, pinpointing agility as a vital component for success in this sector. Their work forms a foundational understanding of the complex operational demands faced by fast-fashion firms. Building upon this, [3] probed into the strategic employment of product scarcity by fast-fashion retailers, suggesting that limited availability can induce a sense of urgency and exclusivity among consumers. This concept of induced scarcity challenges the conventional inventory management wisdom that favors ample stock availability. In examining how industry leaders manage their inventories, [4] showed how companies like Zara gain a competitive edge through rapid stock turnover and agile replenishment strategies, adeptly capitalizing on the volatile nature of fashion trends. [5] added to this narrative by investigating the psychological effects of perceived scarcity on consumer purchasing behavior, indicating that exclusivity and time-limited offers could significantly propel sales. The strategic orchestration of inventory scarcity as a marketing tactic has drawn scholarly attention. [6] discussed how perceived scarcity could act as a potent market signal, potentially enhancing brand value and desirability. Although the impact of scarcity on consumer behavior remains a topic of debate, recent studies have shed light on its multifaceted effects. [7] conducted a field experiment that demonstrated both limited-quantity and limited-time scarcity promotions significantly increased consumers' perceived arousal, subsequently leading to higher rates of impulse purchases. This suggests that strategic scarcity can effectively stimulate immediate demand in an online retail context. However, this approach is not without risks, as [8] cautioned that scarcity strategies can also result in negative consumer reactions like frustration if not managed properly. Addressing a noted deficiency in the literature for a comprehensive theoretical framework that integrates supply chain theory with consumer behavior in the fast-fashion industry, our study seeks to fill this gap. We undertake a meticulous analysis of the dynamic newsvendor model, thoughtfully adapted to the distinctive environment of fast fashion. By extending the discussion beyond mere supply chain efficiency, we investigate how deliberate understocking can be utilized as a strategic tool for market differentiation and profit enhancement. Informed by existing academic discourse, our study pioneers new insights into the strategic implications of understocking and its impact on consumer behavior, a subject of critical relevance in an industry marked by rapid trend cycles and the imperative of timely product availability.

3. Dynamic newsvendor model

We consider a single fast-fashion retailer that introduces new products successively over time. The objective is to characterize the retailer's optimal stocking decisions for two successive products. In a monopolistic setting, the retailer launches two products in two consecutive selling periods. The market sizes Y_i for product $i = 1, 2$ are assumed to be random with probability density function $f_i(.)$ and cumulative distribution function $F_i(a) = \int_0^a f_i(y)dy$. Production costs per unit are c_1 and c_2 for product 1 and product 2, respectively, with market prices p_1 and p_2. The retailer must decide on stocking quantities Q_1 and Q_2 for each product.

Our model deviates from the classical newsvendor inventory model by incorporating demand spillover from one product to its successor. We identify two sources for this spillover: *the word-of-mouth effect* and *the exclusivity effect*. Specifically, customers who miss out on product 1 in period 1, denoted as $(Y_1 - Q_1)^+$, may learn about it through those who purchased it. Hence, the sales volume of product 1 enhances the word-of-mouth effect on $(Y_1 - Q_1)^+$customers, potentially increasing their spillover to product 2. Conversely, the exclusivity effect diminishes as more units of product 1 sell, reducing the likelihood of $(Y_1 - Q_1)^+$customers transitioning to product 2 [9].

We express the combined influence of word-of-mouth and exclusivity as follows: each customer who missed product 1 in period 1 will purchase product 2 in period 2 with a probability $0 \leq G(Q_1) \leq 1$, where $G(Q_1)$is non-decreasing in $Q_1 \in [0, Q_1^{Max}]$, non-increasing in $Q_1 \in [Q_1^{Max}, \infty)$ for some finite Q_1^{Max}. This unimodality of $G(Q_1)$ is practical since the word-of-mouth effect dominates at first and then the exclusivity does. This likelihood gives rise to what we term *'spillover demand'*. Consequently, the total demand for product 2 is:

$$\hat{Y}_2 = \begin{cases} Y_2 + (Y_1 - Q_1)G(Q_1), & Y_1 > Q_1 \\ Y_2, & Y_1 \leq Q_1 \end{cases} \quad (1)$$

Initially, the retailer sets Q_1, then observes the random demand Y_1, followed by setting Q_2 and observing the random demand $\hat{Y}_2$. Excess inventory is assumed to have no salvage value. The total profit is formulated as:

$$\Pi(Q_1, Q_2) = p_1 E[min\{Y_1, Q_1\}] - c_1 Q_1 + p_2 E\left[min\left\{\hat{Y}_2, Q_2\right\}\right] - c_2 Q_2 \quad (2)$$

We propose a marginal analysis to determine the optimal stocking quantities that maximize $\Pi(Q_1, Q_2)$.

3.1 *Marginal analysis*

Consider the retailer's current orders Q_1 and Q_2 for the two products. A decrease in Q_1 by one unit alters the expected total profit $\Pi(Q_1, Q_2)$. We define $\Delta\Pi_2(\Delta Q_1, Q_2)$ as the marginal increase in total profit from product 2 when reducing Q_1 by one unit, keeping Q_2 constant. The marginal change in total profit is then:

$$\Delta\Pi(\Delta Q_1, Q_2) = \left(c_1 + \Delta\Pi_2(\Delta Q_1, Q_2)\right) P(Y_1 \leq Q_1) + (\Delta\Pi_2(\Delta Q_1, Q_2) - (p_1 - c_1))P(Y_1 > Q_1)$$

For a given value Q_2, the optimal Q_1 is found by equating $\Delta\Pi(\Delta Q_1, Q_2) = 0$, yielding the following optimality condition for Q_1,

$$P(Y_1 \leq Q_1) = [(p_1 - c_1) - \Delta\Pi_2(\Delta Q_1, Q_2)] / p_1 \quad (3)$$

Similarly, a decrease in Q_2 by one unit affects $\Pi(Q_1, Q_2)$ as follows:

$$\Delta\Pi(Q_1, \Delta Q_2) = c_2\, P\left(\hat{Y}_2 \leq Q_2\right) - (p_2 - c_2)\, P\,(\hat{Y}_2 > Q_2)$$

This leads to the following optimality condition for Q_2 for a given value of Q_1,

$$P\left(\hat{Y}_2 \leq Q_2\right) = \frac{(p_2 - c_2)}{p_2} \quad (4)$$

Equations (3) and (4) can be solved simultaneously to find the optimal stocking amounts Q_1 and Q_2. We note that for product 2, the stocking problem resembles a classic newsvendor model with demand distribution adjusted for the spillover effect of product 1. Conversely, the optimal stocking quantity for product 1 is less than that of the standard newsvendor solution due to the additional product. This reflects practices of fast-fashion retailers like Zara, which maintain small inventories and introduce variety sequentially. The detailed derivation of total profit and the corresponding optimality conditions are presented next.

3.2 *Optimal stocking quantities*

The retailer aims to maximize the total profit across two periods. Given that $E[min(Y,Q)] = \int_0^Q yf(y)dy + Q\int_Q^\infty f(y)dy = Q - \int_0^Q F(y)dy$ where F is the distribution function of Y, we re-formulate the total profit function:

$$\Pi(Q_1, Q_2) = p_1\left\{Q_1 - \int_0^{Q_1} F_1(y_1)dy_1\right\} - c_1Q_1$$
$$+ p_2\left\{\begin{array}{c} Q_2 - F_1(Q_1)\left[\int_0^{Q_2} F_2(y_2)dy_2\right] \\ -\int_{Q_1}^{Q_1+\frac{Q_2}{G(Q_1)}}\left[\int_0^{Q_2-(y_1-Q_1)G(Q_1)} F_2(y_2)dy_2\right]f_1(y_1)dy_1 \end{array}\right\} - c_2Q_2 \tag{5}$$

Then we apply the Leibniz integral rule [10] to have the first derivatives below.

$$\Pi_{Q_1} := \frac{\partial\Pi(Q_1,Q_2)}{\partial Q_1} = (p_1 - c_1) - p_1F_1(Q_1)$$
$$- p_2\int_{Q_1}^{Q_1+\frac{Q_2}{G(Q_1)}}[F_2\big(Q_2 - (y_1 - Q_1)G(Q_1)\big)\big(G(Q_1) - (y_1 - Q_1)G'(Q_1)\big)]f_1(y_1)dy_1 \tag{6}$$

$$\Pi_{Q_2} := \frac{\partial\Pi(Q_1,Q_2)}{\partial Q_2} = (p_2 - c_2) - p_2F_1(Q_1)F_2(Q_1)$$
$$- p_2\int_{Q_1}^{Q_1+\frac{Q_2}{G(Q_1)}} F_2\big(Q_2 - (y_1 - Q_1)G(Q_1)\big)f_1(y_1)dy_1 \tag{7}$$

Setting $\Pi_{Q_1} = 0$ and $\Pi_{Q_2} = 0$ leads to the first-order conditions below.

(The first-order condition for Q_1 for any given Q_2)

$$\frac{p_1-c_1}{p_1} = F_1(Q_1) + \frac{p_2}{p_1}\int_{Q_1}^{Q_1+\frac{Q_2}{G(Q_1)}}[F_2\big(Q_2 - (y_1 - Q_1)G(Q_1)\big)$$
$$\big(G(Q_1) - (y_1 - Q_1)G'(Q_1)\big)]f_1(y_1)dy_1 \tag{8}$$

(The first-order condition for Q_2 for any given Q_1)

$$\frac{p_2-c_2}{p_2} = F_1(Q_1)F_2(Q_2) + \int_{Q_1}^{Q_1+\frac{Q_2}{G(Q_1)}} F_2\big(Q_2 - (y_1 - Q_1)G(Q_1)\big)f_1(y_1)dy_1 \tag{9}$$

Finding closed-form expressions for (8) and (9) is challenging due to the complexity introduced by the demand spillover effect between the two sequential fashions (products). We also note that $\Pi(Q_1, Q_2)$ in (5) is not concave in general. Thus, a heuristic solution (Q_1^H, Q_2^H) satisfying (8) and (9) is a local maximum, not necessarily a global one, (Q_1^*, Q_2^*). To develop an algorithm for a heuristic solution (Q_2^H, Q_2^H), we derive bounds on the optimal stocking quantities in the subsequent section.

3.3 *Bounds on optimal stocking quantities*

Consider the scenario of "no spillover," where unmet demand in period 1 does not carry over to period 2, implying $G(Q_1) = 0$. Then, the total profit is simply the sum of two independent newsvendors' profits over the two periods as below.

$$\Pi^N(Q_1,Q_2) = p_1E[min(Y_1,Q_1)] - c_1Q_1 + p_2E[min(Y_2,Q_2)] - c_2Q_2 \quad (10)$$

In contrast, with "complete spillover," where all unmet demand in period 1 carries over to period 2, $G(Q_1) = 1$, the total profit is:

$$\Pi^A(Q_1,Q_2) = p_1E[min(Y_1,Q_1)] - c_1Q_1 + p_2E\left[min\left(\tilde{Y}_2,Q_2\right)\right] - c_2Q_2, \quad (11)$$

where $\tilde{Y}_2 = Y_2 + (Y_1 - Q_1)^+$.

Let $(Q_1^*,Q_2^*) \in arg\,max\,\Pi(Q_1,Q_2)$, $(Q_1^N,Q_2^N) \in arg\,max\,\Pi^N(Q_1,Q_2)$, and $(Q_1^A,Q_2^A) \in arg\,max\,\Pi^A(Q_1,Q_2)$. Regarding these order quantities, we need stochastic order relationships by the definition below.

Definition 1: Let Y and Z be two random variables such that $P[Y > \mathrm{u}] \geq P[\mathrm{Z} > \mathrm{u}]$ for all real u. Then Y is said to be smaller than Z in the "usual" stochastic order (denoted by $Y \leq_{st} Z$).

Our findings are summarized through the following propositions:

Proposition 1 : $\Pi^N(Q_1,Q_2) \leq \Pi(Q_1,Q_2) \leq \Pi^A(Q_1,Q_2)$ for any Q_1 and Q_2.

Proof: Since $Y_2 \leq_{st} \hat{Y}_2 \leq_{st} \tilde{Y}_2$, i.e., $P[Y_2 \leq Q_2] \geq P\left[\hat{Y}_2 \leq Q_2\right] \geq P\left[\tilde{Y}_2 \leq Q_2\right]$ for any Q_2, we have $E[min(Y_2,Q_2)] \leq E\left[min\left(\hat{Y}_2,Q_2\right)\right] \leq E\left[min\left(\tilde{Y}_2,Q_2\right)\right]$ in (8), which completes the proof. □

Proposition 2 : $Q_2^N \leq Q_2^* \leq Q_2^A$.

Proof: Since $P[Y_2 \leq Q_2] \geq P\left[\hat{Y}_2 \leq Q_2\right] \geq P\left[\tilde{Y}_2 \leq Q_2\right]$ for any Q_2, the implication holds from

$$P[Y_2 \leq Q_2^N] = P\left[\hat{Y}_2 \leq Q_2^*\right] = \frac{p_2 - c_2}{p_2}.$$

Proposition 3 : $Q_1^N \geq Q_1^* \geq Q_1^A$.

Proof: Since $P[Y_1 \leq Q_1^N] = (p_1 - c_1)/p_1$ and $P[Y_1 \leq Q_1^*] = \left(p_1 - \Delta\Pi_2(\Delta Q_1,Q_2)\right)/(p_1 - c_1)$ for any given Q_2, the first inequality holds. The second inequality holds from replacing Q_1^* with Q_1^A, which yields a larger value of $\Delta\Pi_2(\Delta Q_1,Q_2)$ (or a smaller value of the ratio on the right-hand side) since $(Y_1 - Q_1)G(Q_1) \leq_{st} (Y_1 - Q_1)$.

The outcome of Proposition 1 suggests that the retailer reaps the benefits of the demand spillover effect through elevated average profits. Proposition 2 advises that the retailer should stock product 2 in quantities not less than what would be determined by a newsvendor model lacking any demand spillover effect. Proposition 3 demonstrates that the retailer ought to stock product 1 in quantities less than the newsvendor solution absent any demand spillover effect but not less than the amount for the case when the benefits of demand spillover are fully realized. These bounds are instrumental not only in illustrating the advantages of the demand spillover effect, but also in aiding the development of effective numerical algorithms to ascertain optimal stocking levels. In the following section, we present a numerical experiment to exemplify the benefits of the demand spillover effect within our model.

By Propositions 2 and 3, we can narrow down the search for (Q_1, Q_2) over a 2-dimensional rectangle $[Q_1^A,\ Q_1^N] \times [Q_2^N,\ Q_2^A]$ in R^2. A typical nonlinear programming algorithm with any starting point may lead to a local maximum. Thus, we repeat the algorithm with more starting points so that the best solution may be closer to a global maximum. In the pseudo-code of our algorithm below, a larger *n* is more likely to yield a better heuristic solution.

Initialization step:

Let *S* be the set of randomly sampled *n* points over $[Q_1^A,\ Q_1^N] \times [Q_2^N,\ Q_2^A]$.
Choose a sufficiently small tolerance $\varepsilon > 0$.
$\Pi^H \leftarrow 0$

Main step:

while $S \neq \emptyset$
  Choose a point $s = (Q_1, Q_2)$ in *S*, and use (6) and (7) to evaluate the gradient vector (Π_{Q_1}, Π_{Q_2}) and the Euclidean norm $\|(\Pi_{Q_1}, \Pi_{Q_2})\|_2$.
  while $\|(\Pi_{Q_1}, \Pi_{Q_2})\|_2 > \varepsilon$
    Find a step size $\tau \in \arg\max_{t \geqq 0} \Pi(Q_1 + t\Pi_{Q_1}, Q_2 + t\Pi_{Q_2})$
      s.t. $Q_1^A \leq Q_1 + t\Pi_{Q_1} \leq Q_1^N,\ Q_2^N \leq Q_2 + t\Pi_{Q_2} \leq Q_2^A$.
      (For more details on the line search for τ, see p. 463-475 in [12].)
    if $\Pi^H < \Pi(Q_1, Q_2)$
      $\Pi^H \leftarrow \Pi(Q_1, Q_2)$
      $Q_1^H \leftarrow Q_1$
      $Q_2^H \leftarrow Q_2$
    end if
  end while
  $S \leftarrow S - s$
end while

3.4 *Numerical experiment*

We consider uniformly distributed demand functions for both products as: Y_1, Y_2 ~ Uniform [0, 20] where $L_1 = L_2 = 0$ and $U_1 = U_2 = 20$, and define $G(Q_1)$ as a piecewise linear function with Q_1^{Max}= 10 as below.

$$G(Q_1) = \begin{cases} \frac{Q_1 - L_1}{Q_1^{Max} - L_1}, & L_1 \leq Q_1 \leq Q_1^{Max} \\ \frac{U_1 - Q_1}{U_1 - Q_1^{Max}}, & Q_1^{Max} \leq Q_1 \leq U_1 \end{cases}$$

We set the following selling prices, $p_1 = \$100, \$110, \$120, \$130, \$140$; $p_2 = \$100, \$110$. The unit costs are $c_1 = c_2 = \$50$. This configuration leads to 10 distinct scenarios. For each, we find a heuristic solution (Q_1^H, Q_2^H) for the optimal stocking quantities for both products. We also compute the newsvendor solutions Q_1^N and Q_2^N without considering any demand spillover effect. Across all scenarios, the retailer stocks less of product 1 to create demand spillover effect for product 2, thereby improving overall profits – a clear benefit from intentional scarcity. Interestingly, the total stocking quantities (Q_1^N + Q_2^N) of newsvendor solutions are close to those (Q_1^H + Q_2^H) of heuristic solutions, while the gap between Q_1^H and Q_2^H is significantly larger than that between Q_1^N and Q_2^N. On average, profits increased by 18%, with a peak increase of 36% and a minimum of 5%. These significant profit enhancements underscore the value of intentional scarcity for fast fashion retailers. A summary of the results for each scenario is presented in Table 1.

Table 1

The summary of results from numerical experiment

p_1	p_2	Q_1^N	Q_2^N	$\Pi(Q_1^N, Q_2^N)$	Q_1^H	Q_2^H	$\Pi(Q_1^H, Q_2^H)$	%gap
100	100	10	10	500	5	16	657	31%
100	110	10	11	577	5	17	784	36%
110	100	11	10	577	5	16	701	21%
110	110	11	11	655	5	17	828	26%
120	100	12	10	658	5	16	744	13%
120	110	12	11	735	5	17	872	19%
130	100	13	10	741	8	13	801	8%
130	110	13	11	818	5	17	915	12%
140	100	13	10	829	10	12	872	5%
140	110	13	11	906	8	14	968	7%

4. Summary and conclusion

In this study, we have developed a dynamic newsvendor model that elucidates how a fast-fashion retailer can boost profits by deliberately understocking (scarcity effect) during the current selling period to trigger demand in the subsequent selling period (demand spillover effect). Our model accounts for two primary sources of demand spillover: the word-of-mouth effect and the exclusivity effect. We have demonstrated that it is optimal for the retailer to reduce its stocking quantity for the initial product to foster scarcity and thereby spur demand for the subsequent product in the next selling period. This strategy of introducing new products and adding variety sequentially enables the retailer to stock smaller quantities and yet realize higher profits. We have derived explicit expressions for the optimal stocking quantities. Although these are not in closed form, they can be efficiently solved for optimality since the total expected profit function is unimodal with respect to the stocking quantity of the first product, given any fixed stocking quantity of the second product. Additionally, we have established practical bounds for the optimal stocking quantities by considering scenarios of “no spillover” and “complete spillover” to the subsequent selling period. Our numerical experiment further illustrates the substantial benefits that retailers accrue from deliberate scarcity and the resulting demand spillover effect. We observed that, on average, retailers gain an 18% increase in profits through strategic scarcity. This model sheds light on the advantages that fast-fashion retailers obtain from deliberate undersupply and the energizing effects of demand spillover. We conclude that when display inventory is utilized as an instrument to motivate customer purchases, retailers should carefully evaluate the influence of inventory levels on demand when making effective stocking decisions. Likewise, when stock-outs are likely to create a demand spillover effect, retailers should consider the repercussions of stock-outs on future demand to develop more refined stocking policies. A salient and pragmatic direction for future research is to explore optimal dynamic pricing strategies in conjunction with optimal stocking decisions. Furthermore, investigating the optimal sequence of product introductions, considering various product characteristics, margins, and the benefits derived from scarcity, would be of significant interest.

References

[1] C. H. Chen, “Applying game theory in newsvendor’s supply chain model,” *Journal of Information and Optimization Sciences*, vol. 42, no. 6, pp. 1367–1382 (2021).

[2] M. Fisher and A. Raman, “Reducing the cost of demand uncertainty through accurate response to early sales,” *Operations Research*, vol. 44, no. 1, pp. 87–99 (Jan./Feb. 1996).

[3] G. P. Cachon and R. Swinney, “The value of fast fashion: Quick response, enhanced design, and strategic consumer behavior,” *Management Science*, vol. 57, pp. 778–795 (2011).

[4] F. Caro and V. Martínez-de-Albéniz, “Fast fashion: Business model overview and research opportunities,” in Retail Supply Chain Management, part of the International Series in Operations Research &

Management Science, vol. 223, New York, NY, USA: Springer, pp. 237–264 (2015).

[5] S. Gupta, "The psychological effects of perceived scarcity on consumers' buying behavior," Ph.D. thesis, University of Nebraska, Lincoln, NE, USA (2013).

[6] K. Ferdows, M. A. Lewis, and J. A. D. Machuca, "Rapid-fire fulfillment," *Harvard Business Review*, vol. 82, no. 11, pp. 104–110 (Nov. 2004).

[7] Y. Wu, L. Xin, D. Li, J. Yu, and J. Guo, "How does scarcity promotion lead to impulse purchase in the online market? A field experiment," *Information & Management*, vol. 58, no. 3, p. 103283 (Mar. 2021).

[8] K. Kristofferson, B. McFerran, A. C. Morales, and D. W. Dahl, "The dark side of scarcity promotions: How exposure to limited-quantity promotions can induce aggression," *Journal of Consumer Research*, vol. 43, no. 5, pp. 683–706 (Feb. 2017).

[9] N. Yang and R. Zhang, "Dynamic pricing and inventory management under inventory dependent demand," *Operations Research*, vol. 62, no. 5, pp. 1077–1094 (Sep./Oct. 2014).

[10] M. H. Protter and C. B. Morrey Jr., "Differentiation under the integral sign," in Intermediate Calculus, 2nd ed., Berlin, Heidelberg: Springer-Verlag, pp. 421–426 (1985).

[11] M. Shaked and J. Shanthikumar, Stochastic Orders and Their Applications, San Diego, CA, USA: Academic Press (1994).

[12] S. P. Boyd and L. Vandenberghe, Convex Optimization, New York, NY, USA: Cambridge University Press (2004).

Received December, 2024