Strategic Rationing of E-Commerce Enterprises: Market Demand Shifting and Store Change Rate

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ABSTRACT

As e-commerce grows rapidly, frequent promotional activities on platforms lead to a surge in orders, needing new corporate operational strategies. This paper develops a strategic rationing decision-making model for e-commerce firms during major promotions, focusing on market demand shifts and store-switching rates. It analyzes the impact of discounts, operating costs, and promotion frequency on profits, consumer numbers, and reputation. The study reveals that the optimal satisfaction rate decreases with higher discounts and is influenced by operating costs, while excessive promotions and low satisfaction rates can damage reputation. Contributions include offering a new perspective on e-commerce rationing, enhancing traditional theory with reputation considerations, creating a realistic multi-period model, and validating the model's utility through numerical analysis. This research aids e-commerce firms in strategic planning and enriches academic discourse with new theoretical and empirical approaches.

Keywords: Strategic rationing, Market demand shifting, Store change rate, Loyalty, Discount

1. Introduction

As online shopping develops, the competition between the platforms of major e-commerce enterprises has become increasingly fierce. In order to seize a larger market share, there are an increasing number of e-commerce platforms taking advantage of various opportunities to carry out promotional activities to attract more consumers. From the annual Double 11 Carnival, to the Double 12 Carnival, Goddess Festival, New Year's Day, a variety of e-commerce promotions seem to be overwhelmed, and the volume of orders in each promotion will also increase dramatically compared to the usual. According to Baidu, the real-time logistics order volume of 2020 Tmall Double 11 Global Carnival Season broke 2.25 billion orders, approximately equal to the sum of the annual Chinese Express volume in 2010, and in addition, as of 23:59 on November 11, JD Double 10 produced a total of 264 brands with over 100 million sales, and over 10,000 brands with over 2 times the sales growth in only one day. The above data shows that the order volume during promotional activities is usually

huge, which leads to a surge in costs for e-commerce enterprises (hereinafter referred to as enterprises), which in turn causes huge pressure in the operation process. Faced with a sudden surge in orders during promotional activities, most companies are unable to match their operational capacity and have to invest more, which in turn lead to a considerable increase of costs during the promotional period compared with the regular price period. In the face of such problems, e-commerce companies have adopted strategic rationing strategies during holidays in order to keep costs within a certain range to maximize profits. However, due to insufficient consideration of market demand shifts and store change rates, most enterprises fail to achieve the expected results.

In addition, it will attract some price-sensitive consumers, who may not have a need to shop, but will decide to buy a certain amount of goods during the discount period when they are stimulated by the price discounts, and these consumers are also one of the main target groups of e-commerce platforms. These consumers are also one of the main target groups for price promotions. In both cases, this can lead to a shift in market demand, which in turn affects the profitability of the company's final out-of-stock strategy. In addition, when a firm adopts a rationing strategy, a portion of consumers' needs are not met during the promotional period, causing a negative psychological impression on consumers and affecting customers' loyalty to the firm. Curatman [1] states that customers' commitment to a product, brand, or service is higher than that of competitors in the market, thus causing loyalty behavior, which includes repeat purchases, recommendations to others, and increasing the size or scope of purchases. Therefore, with the strategic rationing behavior of the company, there will be a proportion of consumers subsequently reducing their repeat purchase behavior and choosing to buy from other shops, resulting in a higher rate of shop switching and loss of profit for the company. From the above analysis, it can be observed that both the shift in consumer demand and the change in store change rate will have an influence on the final profit of the enterprise, so the company must consider these two factors while making the final strategic rationing.

At present, some literatures have studied the strategic rationing behavior on e-commerce platforms. Some studies have suggested that one of the factors leading to early purchase is consumers' expectation of inventory shortage [2,3], and that out-of-stock has become more of a deliberate strategic operating strategy for companies. Liu et al. have argued that it is beneficial for companies to adopt strategies that deliberately create stockouts which encourage strategic consumers to buy early [4]. However, these studies are only restricted to a short period and do not consider the negative impact of the enterprise's strategic stockout behavior on consumer psychology in a long-term situation on the subsequent sales of enterprise [5]. Cronin and Taylor pointed out that service quality, including the level of commodity satisfaction, has a remarkable impact on customer repurchase [6]. The out-of-stock behavior of enterprises tends to reduce the repurchase rate of customers, which in turn increases the rate of customer switching and causes the loss of profit for the enterprises.

Therefore, this paper investigates the strategic rationing decision behavior of e-commerce firms under the impacts of market demand shifts and store change rates in the long term. It can be concluded that the optimal satisfaction rate decreases as the discount increases, and the optimal satisfaction rate decreases as the maximum operating cost increases. In addition, if the promotion activities are too frequent, the discounts are strong, and the product satisfaction rates are quite low during the promotion period, it will negatively impact the enterprise's reputation, making its credibility decline. Therefore, this paper further discusses the minimum reputation discount based on the optimal product satisfaction rate, and finally makes a balance between profit, number of consumers attracted, and

reputation to adopt the most superior strategy.

2. Literature Review

In traditional retail supply chains, inventory shortages are generally attributed to the inefficiency of the supply chain [7-9]. However, with the rise of e-commerce, inventory shortages in online sales have gradually evolved into a strategic behavior for companies to pursue higher profits [10]. E-commerce platforms, in the fierce market competition, choose to carry out promotional activities during holidays to attract consumers [11-12]. However, this is accompanied by a surge in order volume and a significant increase in operational costs. To balance costs and stimulate consumer enthusiasm for purchasing, e-commerce enterprises have begun to adopt strategic stockouts to maximize profits [13].

The phenomenon of market demand shift triggered by promotional activities has attracted widespread attention from scholars. Aviv and Pazgal have pointed out that consumers adjust their purchasing timing according to different pricing strategies, leading strategic consumers to shift from the regular pricing period to the discount period [2]. This demand shift significantly impacts corporate profits. If companies consider consumers' strategic behavior when formulating strategies, it could lead to a profit increase of about 20% [14-16]. This indicates that consumers' strategic behavior needs to be deeply understood by companies and incorporated into strategic formulation to achieve profit maximization.

Stockouts not only impose additional costs on consumers but may also lead to profit losses and customer attrition for companies [17-19]. The negative impact of stockout strategies lies in the potential damage to consumers' trust in corporate reputation and service quality [20], thereby affecting customer loyalty. Studies have shown that loyalty, as a reflection of consumer attitudes, significantly influences purchasing decisions [21-23]. A decline in customer loyalty and an increase in the rate of switching stores can reduce a company's long-term profit benefits [24].

In e-commerce, due to the virtual nature of transactions and the intangibility of goods, corporate stockout behavior is more likely to trigger distrust among customers [25]. Therefore, the platform's reputation significantly influences customers' purchasing decisions and is an important consideration for consumers when shopping online. Lo and her colleagues believe that the willingness to purchase is a prerequisite for customers to make a purchase [26-28]. Hence, e-commerce platforms should improve their credit evaluation systems to prevent customer attrition and profit decline due to poor reputation [29-31].

Existing literature has preliminarily explored the formation mechanism of e-commerce companies' intentional stockout strategies, but there is insufficient research on the various factors that need to be considered when formulating strategies. In particular, most existing studies are based on a single period and do not consider the formulation of corporate stockout strategies in the long term and their negative impact on consumer psychology. This paper will fill this gap by analyzing the strategic stockout decision-making of e-commerce companies under the influence of long-term market demand shift and store-switching rate. It will also explore the impact of stockout strategy on corporate reputation, considering the optimal product satisfaction rate, and ultimately make a trade-off between profit, number of consumers attracted, and reputation, adopting the most advantageous strategy.

3. Analysis of Market Demand Shifting Mechanism and Store Change Rate Under Promotion Strategy

3.1 Description of the Problem

This paper studies e-commerce firms selling general products that are price-stable, with adequate and stable supply, and therefore do not consider the problem of stockouts due to insufficient inventory. In addition, considering the different nature of products sold by different e-commerce enterprises, their strategic rationing behavior will have different effects on consumer psychology and repeated purchase decisions, thus resulting in variations in the final total profits of different enterprises in multiple periods. Due to the different nature of the products sold by different e-commerce enterprises, the types and number of substitutes for products, the number of stores selling similar products, and the difference between consumers' product valuation and the actual product price are all different, which will lead to different levels of customer loyalty to products. However, different loyalty and different commodity satisfaction rates and discounts during the discount period will lead to different store change rates, which will further affect the impact of strategic rationing on sales over multiple future periods. Therefore, the strategic rationing behavior of different enterprises will have different degrees of impact on the overall profits of enterprises. For instance, a stockout study conducted by Roland Berger in the United States in 2001 showed that the retail shops in the area had 92.6% of on-shelf rate on the shelves, meaning that the stockout rate of goods reached 7.4%. In the face of the shortage of goods, 40% of consumers adopt the method of reducing consumption expenditure, that is, postponing or canceling the purchase. The sales loss caused by the shortage may account for 3% of the sales, equivalent to US$6 billion annually.

Similar to the loss caused by out-of-stocks in physical shops, out-of-stocks behavior in e-commerce businesses will also lead to a proportionate reduction in sales. For instance, compared with non-food products, food products are now more competitive, with strong substitutability between brands, more choices for customers, and their brand awareness and loyalty to food products are far lower than those of non-food products. Hence, the strategic rationing behavior of food e-commerce enterprises will cause more customers to choose to change stores for purchase in the future, which will result in a greater decline in sales of food e-commerce enterprises than non-food e-commerce enterprises.

Furthermore, if the enterprise conducts frequent promotions with high discounts and low product satisfaction rates, it will affect the image of the enterprise in the minds of customers and reduce its credibility. Therefore, when specifying the discount and satisfaction rate, the impact of this decision on the reputation of the enterprise should be considered.

Different e-commerce platforms can determine the loyalty of customers to their products they sell by analyzing the scale of similar products, the number of competitors of similar products and the customer's valuation of products, and then estimate the rate of store change and the impact on the enterprise's sales profit when strategic rationing is adopted during the promotion period, and make tradeoffs and comparisons under the comprehensive consideration of the impact of this strategy on sales costs and enterprise reputation, to develop an appropriate discount period satisfaction rate and discount to achieve the most superior strategy.

In summary, under the premise of considering strategic consumers and price discount sensitive consumers, and based on the different customer loyalty, satisfaction rate and discount, which will

form different store changing rates, and thus have different impacts on the overall profit of the enterprise, this paper discusses the e-commerce enterprises' strategic rationing decision behavior under the influence of market demand shifting and store changing rate in the long term, and further evaluating the strategic superiority by making a trade-off between profit, cost and reputation.

Table 1. Description of relevant symbols

Symbol	Description	Unit
P	Unit selling price of products in normal sales period	$/unit
V	Consumer's valuation of purchased products	$/unit
N	Total number of fixed consumers of e-commerce enterprises	p
a	Operating cost appreciation	$/unit
X	Scale of similar products	unit
y	Number of competitors	unit
Z	loyalty	0-1
m	Proportion of consumers who choose to change stores due to lack of goods during the promotion period of e-commerce enterprises (Shop change rate).m= Number of people changing stores due to failure to obtain products during the promotion period / Total number of consumers in promotion period	0-1
C1	Operating cost in positive price period	$/unit
C2	Operating cost during promotion period	$/unit
Π	Profit (Π1 Profit in positive price period, Π2 Profit during promotion period）	$/period
f	Satisfaction rate (promotion period)	0-1
U	The consumer surplus of products purchased by consumers at stage j (j=1, 2), where j=1 represents the positive price sales period; j=2 represents a large promotion period	$/unit
D	Consumer demand (D1 Demand in positive price period, D2 Demand in promotion period)	p
ξ	Estimation of Product Availability in Promotion Period by Fixed Consumer Groups	0-1
δ	Discount (promotion period)	0-1
h	Reputation (percentage system)	1-100
s	Ratio of days of promotion period to regular price period	

The specific analysis process is as follows:

1. Determining the superiority of a decision is related to the profit Π, the credibility of the enterprise h and the number of consumers attracted, N. Thus, in this paper, N, h and Π are analyzed.

2. The total number of consumers attracted, N, is the sum of the number of consumers in the positive price period and the promotion period, and the total number of consumers attracted is related to the discount strength of the enterprise. In real life, there is a saturation value for the total number of consumers, set as $Nmax$, which also affects the total number of consumers, N.

3. Total profit of the enterprise in the regular price period and promotion period Π is always related to the discount strength δ, the satisfaction rate f in the promotion period, the total number of consumers N, the commodity price P, the cost c and the change rate m. Therefore, an established model for the total profit of the positive price period and the promotion period Π which comprises the total discount strength δ, the model of promotion period satisfaction rate f, total number of consumers N, commodity price P, cost c and store change rate m.

4. The ratio of the enterprise's credibility h is related to the ratio of promotion period to regular price period *s,* the discount δ, the satisfaction rate f, so the credibility h model of enterprises is established, which comprises the ratio of promotion period to positive price period s, the discount δ, and the satisfaction rate f.

Due to the large price discount during the promotion period, the order quantity will increase significantly compared with the regular price period. When the order quantity exceeds the current operating capacity of the enterprise, e-commerce enterprises need to recruit more delivery personnel, pay producers more overtime and hire more transport vehicles to cope with the increased order quantity. Therefore, the unit operating cost of e-commerce enterprises at this time will increase to a certain extent compared with the regular price period. When the order amount increases to a certain extent, the cost increase will tend to be stable, as shown in Figure 1. Therefore, take the order increase in the promotion period as the horizontal axis, when $D > D1$, the growth trend of C2 will be similar to the arc tangent function, as shown in Figure 2.

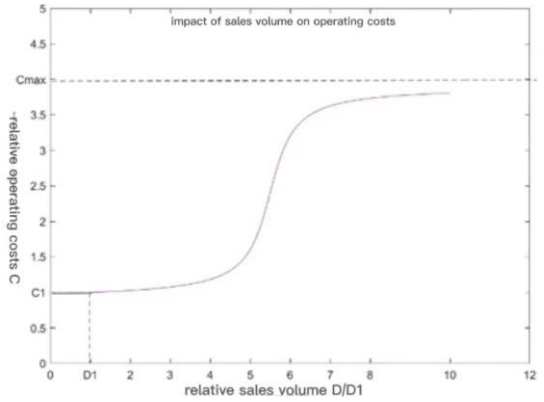

Figure 1. Relative operating cost vs. relative sales volume

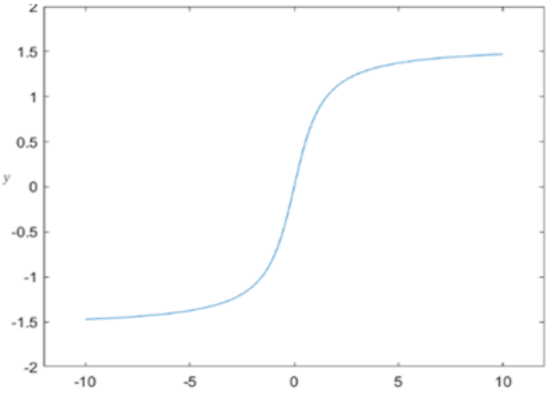

Figure 2. Arc tangent function graph

Therefore, its increase is recorded as

$$a0arctan(a * D + b) + a0arctan(aD1 + b) \quad (1)$$

The total cost during the promotion period can be expressed as

$$c2 = c1 + a0arctan(a * D + b) + a0arctan(aD1 + b) \quad (2)$$

The model is solved as follows:

For simple calculation, when the demand in the promotion period (satisfied part) is equal to the demand in the positive price period, that is, when *D2=D1*, such that point corresponds to the abscissa of the original arc tangent function -10, that is, $Y(D1) = -10$;

When the promotional period demand (satisfied part) reaches 10D1, the promotional period cost C2 reaches the maximum *Cmax*, and *10D1* corresponds to the abscissa 10 of the original arc

tangent function, that is, $Y(10D1) = 10$;

Establish a linear function of the abscissa of the original tangent function with respect to the demand (satisfied part) during the promotion period. From the above assumptions, we can get:

$$b + aD1 = -10 \quad (3)$$

$$b + a(10D1) = 10 \quad (4)$$

As a result,

$$a = 20/9D1 \quad (5)$$

$$b = -110/9 \quad (6)$$

According to the properties of the primitive arc tangent function, $Cmax - c1 = a0\pi$, then $a0 = (Cmax - C1)/\pi$;

To sum up: $c2 = c1 + a0arctan(20/(9D1) * D - 110/9) + a0arctan10$， $(D = D2f)$.

2.2 Analysis of market demand shifting based on consumer choice behavior

In the market, strategic consumers initially have two choices: First, to buy during the regular price period, when they have to pay a higher price for the product but are guaranteed to receive 100% of the product, and the consumer's remaining $U1 = v - p$; Second, to buy during the promotion period, when the consumers can enjoy a lower price, but face the risk of out-of-stock. At this time, consumers have $D2 = v\xi - \delta p$. When U1＜U2, consumers will choose to purchase the product at the time of promotion, otherwise, they will choose to purchase the product at the regular price sale stage ξ. It obeys the uniform distribution on [0,1], so lemma 1 can be obtained.

Lemma 1 There is a unique critical value $\xi^{\wedge} = 1 - (1 - \delta)p/v$, so that when strategic consumers with rigid demand for products meet the expectation of product availability $0 \le \xi < \xi^{\wedge}$, consumers will choose to buy immediately, otherwise they will choose to postpone the purchase until the product promotion period.

Lemma 1 shows that the greater the availability of goods in the promotion period, the greater the discount, the greater the consumer surplus in the promotion period, and more consumers in the original fixed consumer groups will choose to switch their purchase from the positive price period to the promotion period.

In addition, some consumers who did not intend to buy before will buy goods during the promotion, so the total number of consumers in the positive price period and promotion period will increase, but when δ reduces to a certain extent, there is a large gap between the commodity prices in the positive price period and the promotion period, which will have a certain negative impact on consumers' psychology. Besides, there will be some doubts about the product quality, the reputation of the enterprise will decline, and then the total number of consumers will gradually decline. When the discount is large enough, this is set to δ_{min}. Attracted by huge discounts, the number of consumers will gradually increase. Here we use inverse function and quadratic function to fit, and set this function as $N = N0[a/\delta + |-b\delta^2 + c\delta + d|]$ ($N0$ is the total number of customers without promotion)

Without considering the influence of consumers who change shops to buy during the promotion

period, $D1 = [1-(1-\delta)p/v]N0$, $D2 = \frac{(1-\delta)pN0}{v} + (N - N0)$ Therefore, lemma 2 can be obtained.

Lemma 2 When $\delta = 0.1$, then we can get $N = Nmax$. At this time, the influence of quadratic function is ignored, because the influence of the inverse proportional function is far greater than that of the quadratic function when δ is very small, and the influence of the quadratic function can be ignored, in other words $N = N0a/\delta$, $Nmax = N0a/0.1$, Solve these equations to get $a = Nmax/10N0$.

It is found that there is a minimum point of the function through the curve, that is, the minimum value of the function. Here $\delta = \delta_{min}$. It can be seen from the model function that this minimum value is caused by the quadratic function. To facilitate the calculation, we set $\delta_{min} = 0.4$, and the axis of symmetry of the quadratic function is δ= 0.7, bring in to get $c = 1.4b$.

When $\delta = 1$, $N = N0(1 + b - 1.4b + d) = N0$ then $d = 0.4b$.

Finally, consider the impact of the quadratic function on the number of customers, that is, the impact of coefficient b on the number of customers. Because in real life, when businesses carry out promotional activities, the total number of customers in the promotion period and the positive price period will certainly be greater than the number of customers without promotional activities, that is, $N > N0$, so $Nmax/N0 > Nmax/N$ can be obtained. Its function image is shown in the figure 3:

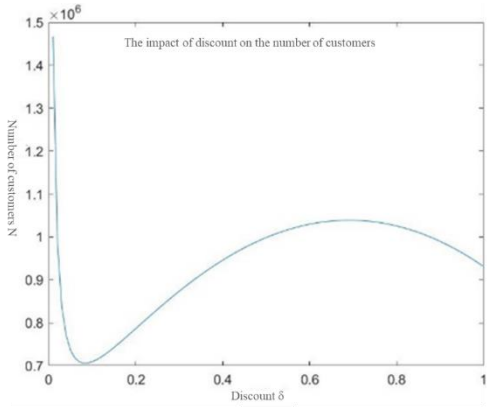

Figure 3. The influence curve of discount on customer quantity

For simple calculation, we choose $\delta = 0.7$, at this time, only the influence of quadratic function is included, $N = (-0.49b + 0.98b + 0.4b)N0 = 0.89bN0$, so $0.89b = ln(Nmax/N0)$, $b = ln(Nmax/N0)/0.89$ can be obtained.

Obtained from the above conditions：

$$\begin{cases} a = Nmax/10N0 \\ b = \ln(Nmax/N0)/0.89 \\ c = 1.4\ln(Nmax/N0)/0.89 \\ d = 0.4\ln(Nma\ \ x/N0)/0.89 \end{cases} \quad (7)$$

When $\delta p - c2 < 0$, the promotional period is unprofitable, and the enterprise will only sell in the positive price period, at this time, $\delta < c2/p$, so when $\delta = c2/p$ is the lowest cost discount.

2.3 Analysis of Store Change Rate

Loyalty reflects customers' attitude towards products to a certain extent. The stable entity school believes that attitude is a relatively stable entity stored in memory, and the evaluation of a thing will be associated with the overall evaluation and initial evaluation [16-17]. It can be seen that customer loyalty to the store will greatly affect the customer's evaluation of the product, affect the customer's

purchase decision, and then affect the store change rate of the enterprise after the enterprise adopts the out-of-stock strategy. Therefore, because customer loyalty is an important affecting factor on the store change rate, it is necessary to analyze it in order to determine the exact value of store change rate.

Since loyalty z will affect the size of m, we will discuss the value of loyalty z.

The size of loyalty z is related to the number of similar alternative products x, the difference between the customer's evaluation of products and the actual price of similar stores y, and the ratio $(v-p)/p$ of the actual price. The larger the number of similar products x and similar shops y, the greater the customer's choice and thus the lower the loyalty to the product. The greater the ratio between the difference between the customer's valuation of the product and the actual price of the product, the higher the customer's valuation of the product and the greater the utility of the product, and consequently the less likely the customer is to change shops and the more loyal they are to the product. Therefore, x and y are inversely correlated and positively correlated with $(v-p)/p$.Therefore, the product parameter set $\frac{(v-p)}{p}/(x*y)$ is made.

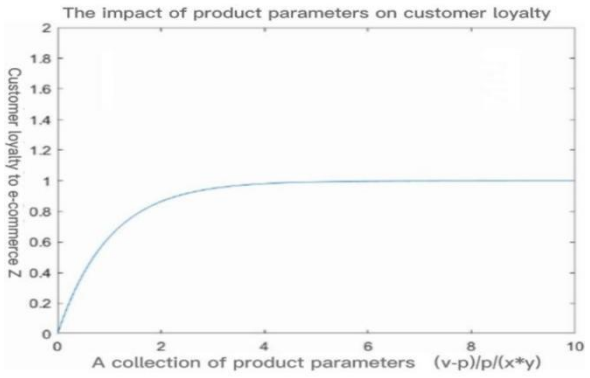

Figure 4. Influence curve of product parameters on customer loyalty

For simplification, z belongs to (0, 1)

$$Z = 1 - e^{-\frac{w\left[\frac{(v-p)}{p}\right]}{x*y}} \tag{8}$$

The model is solved as follows:

When the number of similar products in the market $x = 10$, the number of similar stores $y = 10$, $(v-p)/p = 1$, that is, the product is irreplaceable, the store is irreplaceable, and the customer's valuation of the product is twice the actual price of the product, the customer's loyalty to the product will approach 1, so simply set the value to 0.99.

$$Z = 1 - e^{-w} = 0.99 \tag{9}$$

The solution shows that $w = 460$,

$$Z = 1 - e^{-\frac{460\left[\frac{(v-p)}{p}\right]}{x*y}} \tag{10}$$

When $x = 1000$, $y = 100$, $(v-p)/p = 0.1$, that is, there are many similar products, many competitors, and the customer's valuation is close to the actual price of the product, and the customer's

loyalty is very low at this time. Using our model, we can get $z = 0.00046$. It can be seen that z is so small, that is, the customer's loyalty is very low, which is consistent with the actual situation, so the simplification of the model is reasonable.

This paper considers that the out-of-stock behavior will have a certain impact on consumer psychology. Therefore, with the difference of customer loyalty to products, product satisfaction rate and discount rate during the promotion period, a certain proportion (m) of consumers facing out-of-stock during the promotion period will no longer buy from this store in the future for a period of time and will choose to change stores. The rate of store change m, discount rate δ， The satisfaction rate f is related. The higher the loyalty of customers, the less likely they are to change to another stores. The lower the store change rate is, the greater the negative impact of the lower product satisfaction rate on customer psychology, and the higher the change rate will be; The greater the discount rate, the greater the consumer surplus, so the lower the store change rate. To sum up, z and f are inversely related δ positive correlation.

Figure 5. The curve of the influence of decision behavior on the rate of store change

When m is between [0,1], when the satisfaction rate f or loyalty z tends to 0, m will tend to 1.

$$m = 1 - e^{-\frac{\delta k}{z*f}} \tag{11}$$

The model is solved as follows:

When $z = 0.1$, $f = 0.1$, $\delta = 1$, that is, the customer's loyalty to the product is very low, the product satisfaction rate of the merchant during the discount period is also low, and the discount intensity is very small, then the probability of the customer changing store will be large, approaching to 1. For simplicity, let $m = 1$.

From this, it can be concluded that:

$$m = 1 - e^{-\frac{0.046\delta}{z*f}} \tag{12}$$

When $z = 1$, $f = 1$, $\delta = 0.1$, that is, there are many similar products, that is, customer loyalty to the product is high, the satisfaction rate of the products during the discount period is also high, and the discount intensity is large, then the probability of customers changing stores is very small. Using our model, we can get $m = 0.0046$. It can be seen that m is very small, that is, the rate of store change is very small, which is in line with the actual situation, so the simplification of the model is reasonable.

4. Profit Analysis of Strategic Rationing Decision of E-Commerce Enterprises Under the Influence of Market Demand Transfer and Store Change Rate

4.1 Basic Assumptions of the Model

1. The price of this product is stable, the supply of goods is sufficient and stable, and the shortage caused by insufficient inventory is not considered.

2. There are two types of consumers in the market: strategic consumers and price discount-sensitive consumers.

3. Due to the different experiences of each consumer group, the estimation of stockout will also be different. For the consumer group as a whole, ξ is assumed to obey the uniform distribution on [0,1]

4. Consumers at the same income level have the same valuation for the same commodity. This paper only analyzes consumers at a certain income level.

5. Set the reputation h of the enterprise as the percentage system, $0 \leq h \leq 100$.

3.2 Profit Estimation of Enterprise Strategic Rationing Strategy Considering the Influence of Store Change Rate.

The profit of e-commerce enterprises in the positive price period of products is

$$\pi 1(p-c1)[1-(1-\delta)p/v]N0 \tag{13}$$

Without considering the impact of store change rate, the demand of e-commerce enterprises during the promotion period is $D2$, and the profit of enterprises can be written as

$$\pi 2 = (\delta p - c2)\left[\frac{(1-\delta)pN}{v} + (N - N0\,)\right]f \tag{14}$$

Considering the strategic rationing behavior of e-commerce enterprises, due to the loyalty, the product satisfaction rate and discount rate of consumers who buy during the promotion period are different, which in turn leads to different store change rates caused by the strategic rationing behavior. During the promotion period, different proportions of consumers will no longer buy in the store, which will have a certain impact on the sales and profits of enterprises. For simplicity, this effect is reflected by multiplying the total sales profit of the two stages by a certain proportion m.

$$\pi_t = \pi 1 + \pi 2 - m\pi 2 \tag{15}$$

$$= \frac{p-c1}{D1} + (\delta p - c2) * D2 * f * (1-m)$$

$$= (p-c1)\left[1-\frac{(1-\delta)p}{v}\right]N0 + (\delta p - c2)\left[\frac{(1-\delta)pN0}{v} + (N-N0)\right]f * (e^{-\frac{\delta k}{z*f}})$$

$$= (p-c1)\left[1-\frac{(1-\delta)p}{v}\right]N0 + (\delta p - c2)\left[\frac{(1-\delta)pN0}{v} + (N-N0)\right]f * (e^{-\frac{0.046\delta}{z*f}})$$

The find function in MATLAB can be used to obtain Π total maximum value and the corresponding f_m value of m.

5. Reputation Evaluation under Enterprise's Promotion Activities and Shortage Strategy

In modern economic society, reputation is not only a moral norm but also an important resource that can bring economic benefits to enterprises. Online trust has played an important role in the growth

of online market platforms over traditional incumbents in many service industries [37]. Tahir Islam [38] concluded that customer satisfaction, corporate reputation, and customer trust are the key antecedents of customer loyalty and purchase intention. From a game-theoretic perspective, information about a seller's reputation helps to promote buyer trust [39]. Besides, favorable reputations allow new ventures to signal their quality and stand out in a crowded market [40]. Therefore, when enterprises carry out promotion activities and formulate corresponding out-of-stock strategies to maximize profits, they should also consider the impact on the reputation of enterprises. After discussing the optimal satisfaction rate under the condition that enterprises pursue profit maximization, this paper takes credit into account, so that enterprises can balance profit and credit.

Reputation h and the ratio of promotion period to positive price period s, discount rate δ, The satisfaction rate f is related. The higher the ratio s $(0 \leq s \leq 1)$ of promotion period to the regular price period, the lower the reputation of the enterprise, and the smaller the h; Discount rate δ the greater the satisfaction rate, the higher the reputation of the enterprise. To sum up, the reputation of enterprises h is inversely related to s, and positively correlated with δ and f, and these three factors have similar impact on reputation. Therefore, set the factors of decision behavior as $(\delta^n f^m s^q)$, in order to facilitate the calculation, the model is simplified, assuming that $n = 1,\ f = 1,\ q = -1$. Reputation h maps $\delta^n f^m s^q$, as shown in figure.

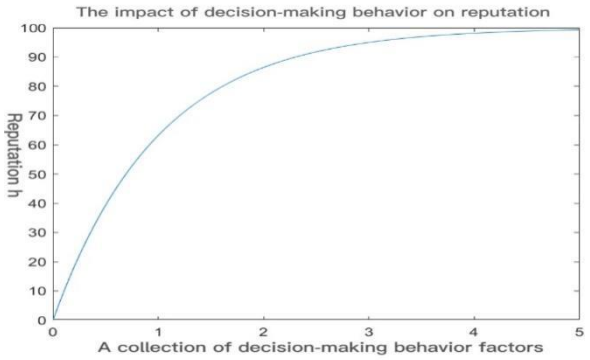

Figure 6. Influence curve of decision behavior on reputation

The curve is simulated to get the function: $h = 100\left[1 - e^{-t\delta\left[\frac{(D1+D2f)}{D}\right]3/s}\right]$

The model is solved as follows: when $s = 1,\ f = 0.1,\ \delta = 0.05$, that is, the number of promotion periods is the same as that of regular price periods. During the promotion period, the satisfaction rate of goods is very low and the discount is very strong. This will make consumers doubt the products sold by the merchants, and the reputation of the merchants will be very low. For simplicity, the reputation h is set to 0.1.

From this we can get $h = 100\left[1 - e^{-t\delta\left[\frac{(D1+D2f)}{D}\right]3/s}\right] = 0.1$

The solution is $t = 0.12$

$$h = 100\left[1 - e^{-0.12\delta\left[\frac{(D1+D2f)}{D}\right]3/s}\right] \tag{16}$$

When $s = 0.01,\ f = 1, \delta = 1$, that is, the number of promotion periods is much smaller than that of positive price periods. During the promotion period, the satisfaction rate of goods is very high

and the discount is very small, almost no discount. Using our model, we can get $h = 99.9955$. It can be seen that h is very large, approaching 100, that is, the reputation of merchants is very high, consistent with the actual situation, so the simplification of the model is reasonable.

Reputation has a great impact on e-commerce enterprises, so we take the reputation h as the minimum, which should not be less than 60, and the discount here is the minimum reputation discount.

6. Analysis of Strategic Superiorities

When formulating the optimal satisfaction rate, an enterprise should not only consider the maximization of profits, but also the credibility of the enterprise and the number of consumers attracted. Apparently, when the profits are larger, the credibility of the enterprise is higher, and the number of consumers attracted is larger, the decision-making behavior will be more superior. Hence, we set the quantitative index of superiority q to measure the decision-making behavior. When q is greater, the decision will be better.

Because profits Π, the reputation of the enterprise h and the number of consumers attracted N will both affect the size of superiority q, and the degree of influence varies, so we assume that q is the power product of N, Π, h, i.e. $q = (\frac{\pi}{\pi_{\delta=1}})^n(\frac{h}{100})^m(\frac{N}{Nmax})^p$, n, m, p according to the influence degree of N, Π, h is set as 3, 2 and 1 respectively in this paper.

In the result, we can see the customer's loyalty to the product z and the store change rate m under the given parameters, and then we can determine the parameter value of the best satisfaction rate f of the product during the promotion period. On this basis, we can see the reputation of the merchant at this time, and determine the minimum credit discount. The superiority of the shortage strategy is then determined, considering the total customer quantity N, the minimum cost discount and the minimum reputation discount, and then the appropriate satisfaction rate and discount during the discount period are formulated. If $P = 100$, $v = 120$, $s = 0.15$, $c1 = 20$, $x = 10$, $N0 = 1000$, $\delta = 0.6$, $y = 10$, $Nmax = 10000$, the results of numerical analysis are shown in Figure 7. It can be seen that the profit tends to increase and then decrease relative to the satisfaction rate, and there is an optimal satisfaction rate fm at this time.

Next, we can enter different parameter values to facilitate vertical comparison. The change in profit relative to satisfaction rate will show different trends, as shown in Figure 7 - Figure 10.

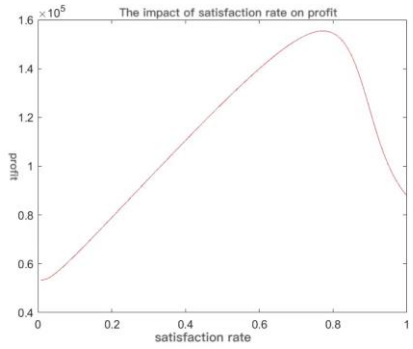

Figure 7. The impact of satisfaction rate on profit

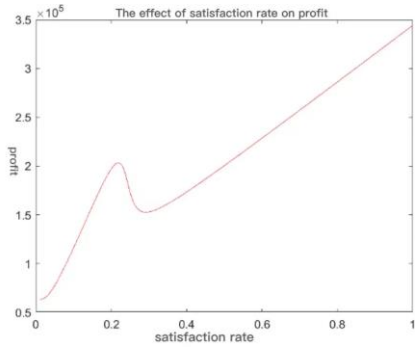

Figure 8. The impact of satisfaction rate on profit

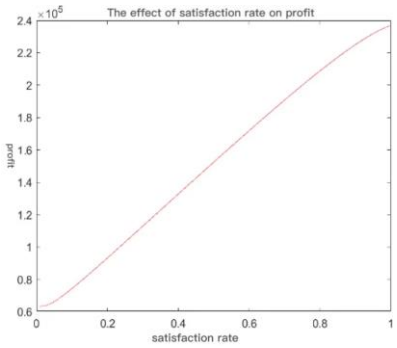

Figure 9. The impact of satisfaction rate on profit

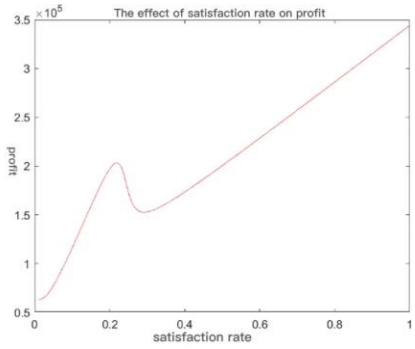

Figure 10. The impact of satisfaction rate on profit

7. Numerical analysis

To show the impact of changes in different influencing factors in the above decision-making process on the final optimal satisfaction rate of the enterprise, the following categories are used for relevant numerical analysis.

7.1 Discount Impact Analysis

Take $P = 100$, $v = 120$, $s = 0.15$, $c_1 = 20$, $x = 10$, $N0 = 1000$, $y = 10$, $Nmax = 10000$, $Cmax = 60$ respectively.

When these parameter values are fixed, only the discount δ is varied. Take $\delta = 0.8$, $\delta = 0.7$, $\delta = 0.65$, $\delta = 0.6$ respectively for numerical analysis. We can see that the profit about the satisfaction rate shows different trends, and with the increase of discount, the optimal satisfaction rate will gradually decrease. The results of experimental values are consistent with that of theoretical analysis, which is in line with the actual situation. The output results are shown in Figure 11 - Figure 14.

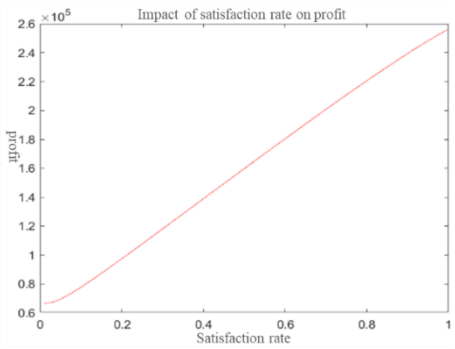

Figure 11. Impact of satisfaction rate on profit

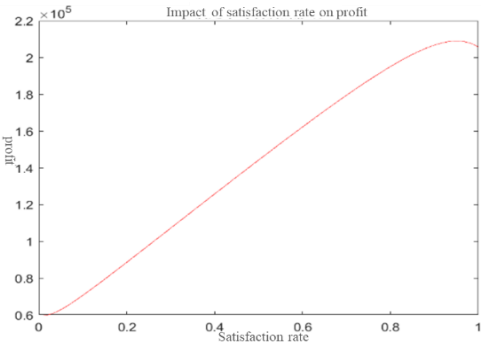

Figure 12. Impact of satisfaction rate on profit

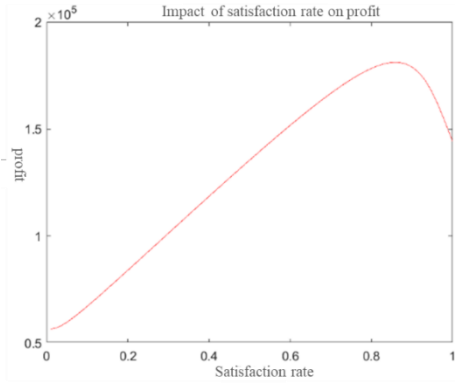

Figure13. Impact of satisfaction rate on profit

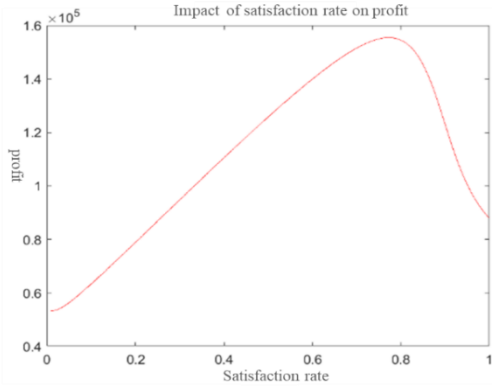

Figure 14. Impact of satisfaction rate on profit

7.2 Highest Cost Impact Analysis

Take $P = 100$, $v = 120$, $s = 0.15$, $c_1 = 20$, $x = 10$, $N0 = 1000$, $y = 10$, $\delta = 0.6$, $Cmax = 60$ respectively, the output results are shown in Figure 15 - Figure 18. When the values of these parameters are fixed, only the maximum operating cost $Nmax$ is changed, and $Nmax$ will be taken as 1000000, 100000, 50000, and 5000 respectively for numerical analysis. We can see that the profit is on a different trend regarding the satisfaction rate. The optimal satisfaction rate fm decreases first and then increases with the increase of $Nmax$, which is consistent with the actual situation. When the total number of consumers in the market is not large, the optimal satisfaction rate fm in the promotion period is low for the consideration of the cost in the promotion period. However, when the total number of consumers in the market increases to a certain level, more customers are attracted to the promotion, which to a certain extent weakens the impact of the cost increase on profits, and the optimal satisfaction rate fm in the promotion period gradually increases. The experimental results are consistent with the theoretical analysis and conform to the actual situation.

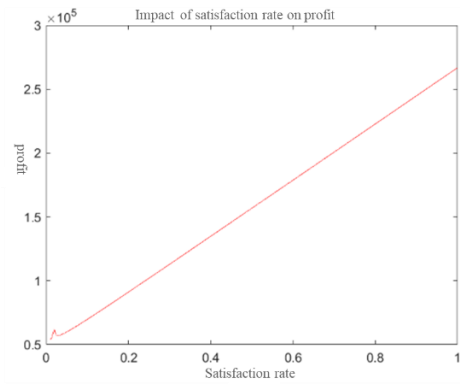

Figure 15. Impact of satisfaction rate on profit

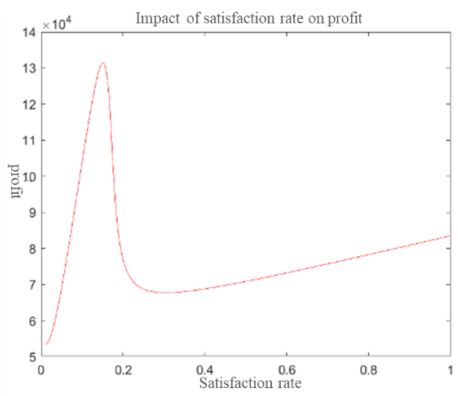

Figure 16. Impact of satisfaction rate on profit

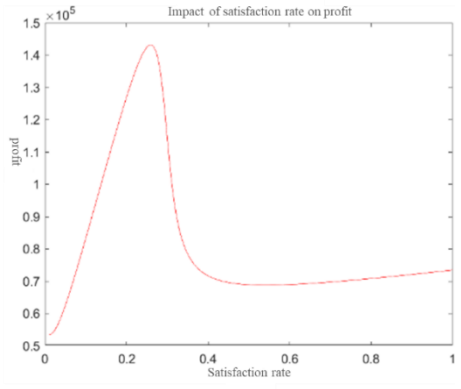

Figure 17. Impact of satisfaction rate on profit

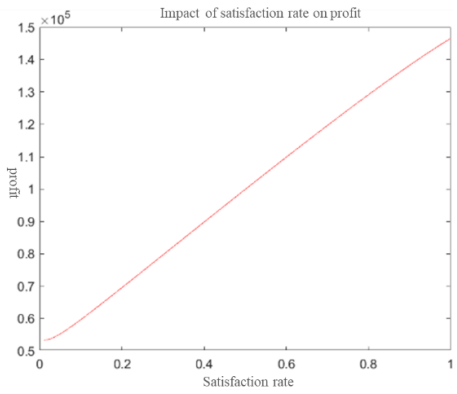

Figure 18. Impact of satisfaction rate on profit

7.3 Impact of Total Market Consumers

Take $P = 100,\ v = 120,\ s = 0.15,\ c_1 = 20,\ x = 10,\ N0 = 1000,\ y = 10,\ \delta = 0.6,\ Cmax = 60$ respectively. When the values of these parameter are fixed, only the size of $Nmax$ of the total number of consumers in the market will be changed, and $Nmax$ will be taken as 1000000, 100000, 50000 and 5000 respectively for numerical analysis. We can see that the profit has different trends with respect to satisfaction rate. The optimal satisfaction rate fm decreases first and then increases with the increase of $Nmax$, which is consistent with the actual situation. Because when the total number of consumers in the market is not large, the optimal satisfaction rate fm in the promotion period is low due to the cost in the promotion period. However, when the total number of consumers in the market increases to a certain extent, more customers are attracted by the promotion activities, which to a certain extent weakens the impact of increased costs on profits, and the optimal satisfaction rate fm in the promotion period gradually increases. The experimental results are consistent with the theoretical analysis, and conform to the actual situation. After inputting relevant parameters in the GUI window, the output results are shown in Figure 19 - Figure 22.

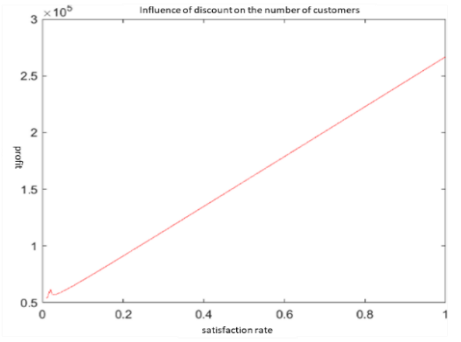

Figure 19. Influence of discount on the number of customers

Figure 20. Influence of discount on the number of customers

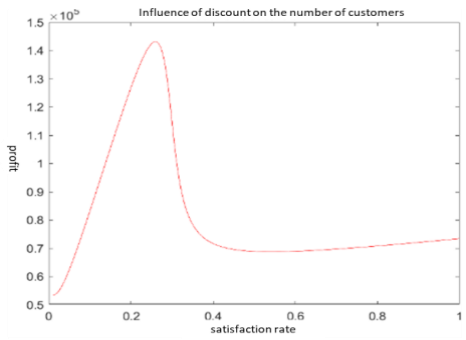

Figure 21. Influence of discount on the number of customers

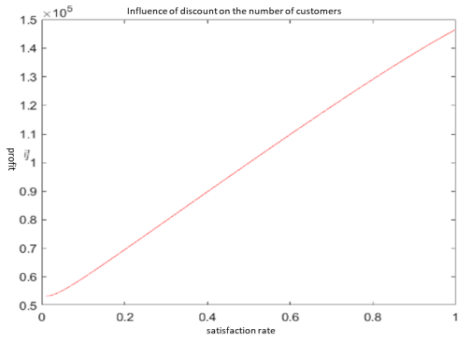

Figure 22. Influence of discount on the number of customers

8. Conclusion

Strategic rationing is a common decision-making behavior adopted by current e-commerce enterprises and is the natural result of enterprises' pursuit of profit maximization. Therefore, a comprehensive analysis of the factors that enterprises need to consider when making out-of-stock strategies will help enterprises make the most advantageous decisions and maximize the benefits in the long run. This paper studies the strategic rationing decision behavior of e-commerce enterprises under the influence of market demand shifting and store change rate in the long term, and evaluates the superiority of the decision behavior by introducing the factor of credibility. The results show that different parameters correspond to different optimal satisfaction rates. The optimal satisfaction rate decreases with the increase of discount, the maximum operating cost and the total number of consumers in the market. The optimal strategic rationing of an enterprise is to select the appropriate discount and the corresponding optimal satisfaction rate under the given conditions, so that the corresponding superiority value of the strategy is the maximum value under the influence of two factors, namely, customer demand shifting and store change rate, combined with reputation evaluation, and then the enterprise can obtain the maximum economic benefits. Therefore, under different market conditions, enterprises can establish different discounts and select the corresponding optimal satisfaction rate, and then compare the superiorities of each strategy combination on this basis to select the most superior strategy combination to obtain the maximum economic benefits.

Market demand shift and consumer store-switching rate are innovatively incorporated as two core factors affecting the strategic inventory decision-making of e-commerce enterprises. A decision-making model that comprehensively considers both factors has been constructed, filling the gap in existing literature that only considers single factors. This provides a theoretical basis for enterprises to formulate more cost-effective promotional strategies. This paper not only considers the impact of promotional frequency and product satisfaction rate on enterprise reputation but also further explores the comprehensive effect of promotional discounts and consumer loyalty on reputation, enriching the theoretical system of enterprise reputation management.

However, for the convenience of analysis, this paper only analyzes consumers at a certain income level, whereas the valuation of the same good may vary across income levels. Therefore, the following research can be carried out for consumers at different income levels. In addition, this paper

only considers the estimation of product availability by fixed consumer groups during the promotion period ξ. The distribution is uniform on $[0, 1]$, but it is not necessarily uniform in real life, which is also the direction of future research.

Acknowledgments

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References

[1] Curatman, A., Suroso, A. and Suliyanto, S. Loyalty program and communication effectiveness as drivers of store loyalty. Meas. Bus. Excell. 2021, 26, 417-432.

[2] Aviv, Y. and Pazgal, A. Optimal pricing of seasonal products in the presence of forward-looking consumers. M&SOM-Manuf. 2008, 10, 339-359.

[3] Zhang, D. and Cooper, W. Managing clearance sales in the presence of strategic customers. Prod. Oper. Manag. 2008, 17, 416-31.

[4] Liu, Q., Garrett, J. and Ryzin, V. Strategic capacity rationing to induce early purchases. Manage. Sci. 2008, 54, 1115-1131.

[5] Xiayang, W. and Bin, Z. Research on e-commerce strategic stock out under consumer choice behavior, JMSE. 2019, 22, 9-23. (In Chinese)

[6] Cronin, J. and Taylor, S. Measuring service quality-a reexamination and extension. J. Mark. 2012, 56, 55-68.

[7] Raman, A., DeHoratius, N. and Ton, Z. Execution: The missing link in retail operation. Calif. Manage. Rev. 2001, 43, 136-151.

[8] DeHoratius, N. and Raman, A. Inventory record inaccuracy: An empirical analysis. Manage. Sci. 2008, 54, 627-641.

[9] Ettouzani, Y., Yates, N. and Mena, C. Examining retail on shelf availability: Promotional impact and a call for research. Int. J. Phys. Distrib. Logist. Manag. 2012, 2, 213-243.

[10] Liu, Q., Zhang, X., Huang, S., Zhang, L. and Zhao, Y. Exploring consumers' buying behavior in a large online promotion activity: the role of psychological distance and involvement. J. theor. appl. electron. commer. Res. 2020, 15, 66-80.

[11] Lowe, B. Consumer perceptions of extra free product promotions and discounts: the moderating role of perceived performance risk. JPBM. 2010,19, 496-503.

[12] Peikofer, S., Esper, T. and Howlett, E. Hurry! Sale ends soon: The impact of limited inventory availability disclosure on consumer responses to online stockouts. J. Bus. Logist. 2016, 37, 231-246.

[13] Tong, T., Xu, X. and Yan, N. Impact of different platform promotions on online sales and conversion rate: The role of business model and product line length. Decis. Support Syst. 2022, 156, 113746, 1-12.

[14] Cai, J., Zhou, Q. and Sun, J. Competition model and coordination mechanism considering strategic customer behavior under vendor-managed inventory. Int. Trans. Oper. Res. 2021, 28, 2782-2809.

[15] Peinkofer, S.T., Esper, T. L., Smith, R.J. and Williams, B.D. Assessing the Impact of Price Promotions on Consumer Response to Online Stockouts. J. Bus. Logist. 2015, 36, 260-272.

[16] Sarah, G.J. and Moore, S.G. Yes, we have no bananas: Consumer responses to restoration of freedom. J. Consum. Psychol. 2014, 24, 541-548.

[17] Kurata, H. How does inventory pooling work when product availability influences customers' purchasing decisions? Int. J. Prod. Res. 2014, 52, 6739-6759.

[18] Knobloch-Westerwick, S., Johnson, B.K.; Westerwick, A. Confirmation Bias in Online Searches: Impacts of Selective Exposure Before an Election on Political Attitude Strength and Shifts. J. Comput.-Mediat. Commun. 2015, 20, 171-187.

[19] Lai C.K., Hoffman, K.M. and Nosek, B.A. Reducing Implicit Prejudice. Soc. Personal. Psychol. Compass, 2013, 7, 315-330.

[20] Rosario, A.B., Sotgiu, F., K. and Bijmolt, T.H.A. The Effect of Electronic Word of Mouth on Sales: A Meta-Analytic Review of Platform, Product, and Metric Factors. J. Mark. Res. 2016, 53, 297-318.

[21] Nahiduzzaman, K.M., Aldosary, A.S. and Mohammed, I. Framework Analysis of E-Commerce Induced Shift in the Spatial Structure of a City. J. Urban Plan. Dev. 2019, 145(3), 04019006.1-04019006.11.

[22] Niu, B., Dong, J., Dai, Z. and Liu, Y. Sales Data Sharing to Improve Product Development Efficiency in Cross-border E-commerce. Electron. Commer. Res. Appl. 2021, 101112.

[23] Castro-González, S., Bande, B. and Fernández-Ferrín, P. Influence of companies´ credibility and trust in corporate social responsibility aspects of consumer food products: The moderating intervention of consumer integrity. Sustain. Prod. Consump. 2021, 28, 129-141.

[24] Jung, I.N., Sharma, A. and Anna, S.M. The impact of supermarket credibility on purchase intention of novel food, J. Retail. Consum. Serv. 2022, 64, 102754.

[25] Sen S. and Bhattacharya, C.B. Does Doing Good Always Lead to Doing Better? Consumer Reactions to Corporate Social Responsibility. J. Mark. Res. 2001, 38, 225-243.

[26] Lo, F.Y., Yu, T.H. and Chen, H.H. Purchasing intention and behavior in the sharing economy: Mediating effects of APP assessments. J. Bus. Res. 2020, 121, 93-102.

[27] Ramesh, S. Estimating credit worthiness using profit modeling. International Conference on Artificial Intelligence and Machine Learning (ICAIML 2020) 4TH-5TH September 2020, Jaipur, India. 2020, 1049, 012020.

[28] Truong, Y., Ackermann, C.L. and Klink, R.R. The role of legitimacy and reputation judgments in users' selection of service providers on sharing economy platforms. Inf. Manage. 2021, 58, 103529.

[29] Islam, T., Islam, R., Pitafi, A.H., Liang X., Rehmani, M., Muhammad, I. and Muhammad, S.M. The impact of corporate social responsibility on customer loyalty: The mediating role of corporate reputation, customer satisfaction, and trust. Sustain. Prod. Consump. 2021, 25, 123-135.

[30] Jiao, R., Przepiorka, W. and Buskens, V. Reputation effects in peer-to-peer online markets: A meta-analysis. Soc. Sci. Res. 2021, 95, 102522.

[31] Hoos, F. Showing off or showing impact? The joint signalling effect of reputation and accountability on social entrepreneurs' crowdfunding success. Manage. Account. Res. 2022, 54, 100778.