Hindawi
Discrete Dynamics in Nature and Society
Volume 2023, Article ID 3172590, 14 pages
https://doi.org/10.1155/2023/3172590

Research Article

Dual-Channel Supply Chain Coordination with Loss-Averse Consumers

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Received 9 September 2022; Revised 4 November 2022; Accepted 15 November 2022; Published 1 March 2023

Academic Editor: Reza Lotfi

Most studies on supply chain coordination assume that consumers are rational. However, with the development of e-commerce, consumer-bounded rationality has become an important issue with respect to supply chain coordination. Based on the assumption that some consumers are loyal to the offline shop and others are reference-dependent, this article examines the mechanism of vertical restraints and their competitive effects. This research study found that compared with the assumption of rational consumers used in previous literature, vertical restraints help internalize the "channel price gap externality" when consumers are loss averse. When separately operating, the offline shop will set a higher price due to its consumers' higher loyalty and willingness to pay. However, given the positive externality of this price to the online retail sales, the offline price is still lower than the level under vertical integration. When the upstream manufacturer achieves supply chain coordination with vertical restraint contracts, the channel price gap externality is internalized, and the channel price gap expands to stimulate loss-averse consumers' purchasing decisions.

1. Introduction

On August 12, 2016, the Shanghai Municipal Development & Reform Commission decided to impose administrative penalties on Chongqing Haier Home Appliance Sales Co., Ltd. Shanghai Branch and others for using minimum resale prices. According to the penalty decision, these three manufacturers involved entered into distribution contracts with downstream retailers to limit their minimum retail prices at different sales terminals. Since 2013, the three manufacturers sent monthly online and offline price lists to distributors by direct delivery or by mail, requiring that "the center's activities shall not be lower than this price in any form without filing." Through this distribution contract, these three upstream manufacturers, in effect, vertically constrained the supply chain by limiting the minimum resale prices of goods. Unlike the resale price maintenance cases investigated by the anti-monopoly bureau in the past, this case involved price maintenance that appeared to differ between the online and offline sales channels. In fact, in some markets, such as home appliances, there are clear and significant price gaps between online and offline channels. The existence of such price gaps has greatly facilitated the sales of home appliances in the online market. According to the "2015 China Online Home Appliance Shopping Analysis Report," the size of China's online home appliance market reached 2,007 billion in 2015, a 49% year-on-year increase. In stark contrast, the retail sales of offline home appliances fell by 3.8% during the same period. By observing the sales pages of online channels, it is easy to observe that labels such as "counter price" and "original price" frequently appear below the actual price to encourage consumers to purchase online. However, previous studies on supply coordination with resale price maintenance and other vertical restraints have not considered the impact of online and offline price gaps on consumer behavior [1–3].

With the continuous development of big data analysis technology and e-commerce, firms are able to adjust their pricing and marketing strategies by observing consumers' purchasing behaviors. Reference dependence and loss aversion are two typical behaviors associated with consumers' bounded rationality, and both are important core aspects of prospect theory. Reference-dependent consumers have a reference point when making purchase decisions. Thus, when consumers purchase a product with a price below the reference point, there is an additional psychological utility gain. In contrast, there is an additional psychological utility loss when purchasing at a price above the reference point. Thaler [9] first suggested that consumers are reluctant to buy a product at a price higher than the reference price because of the expected utility loss associated with paying more than the reference price. Consistent with this, there is a wealth of evidence from behavioral economics and marketing that suggests consumers are reference-dependent and exhibit loss aversion in their utility [10, 11]. Accordingly, loss-averse consumers incur greater subjective utility losses from losses relative to the utility improvement from gains of the same magnitude.

According to the abovementioned concepts, incorporating consumer loss aversion into a supply chain coordination model helps to explain price gaps and comprehensively analyze the welfare effect of vertical integration in such markets. Hence, based on the prospect theory, this article presents a possible mechanism for manufacturers in the multichannel retail industry to implement vertical restraints, such as resale price maintenance, in the presence of loss-averse consumers. Therefore, the main contributions of this article are as follows:

(1) This article presents a mathematical framework for analyzing dual-channel coordination when consumers are loss averse

(2) The model proposed in this article yields new economic insights in the competitive effect and anticompetitive effects of vertical restraints by relaxing the standard assumption that consumers are rational

(3) This analysis suggests that when consumers are bounded rationally, manufacturers have more incentive to impose vertical restraints

The remainder of the article is organized as follows. Section 2 presents a literature review, while Section 3 discusses the basic model. The results and sensitivity analyses are provided in Section 4, which is followed by a discussion of the managerial and antitrust policy insight in Section 5. Finally, Section 6 presents the conclusion, limitations of the study, and suggestions for further research studies.

2. Literature Review

Whether vertical restraints restrict channel competition is a current focus of industrial organization literature. However, the theory of vertical restraints is less well-developed than the mature theory of horizontal agreements. Many theoretical issues remain to be resolved. Nonetheless, most previous literature on vertical restraints and vertical integration assume that consumers are completely rational. Under this assumption, theoretical research can be divided into two branches. One branch argues that vertical coordination adheres to the efficiency promotion theory, while the other branch argues that the anticompetitive effect dominates. Efficiency promotion theory suggests that vertical restraints improve coordination among the components of the vertical value chain and increase consumer surplus and total social welfare by eliminating double markups [1, 2], thereby solving the problem of service free-riding among retailers [3] and signaling quality information about goods signaling quality information about goods [4, 5]. The anticompetitive effects of vertical restraints are reflected in weakening inter-brand competition [6], facilitating collusion among manufacturers [7], and promoting the leverage effect and the exclusion effect [8].

However, a large body of evidence from behavioral economics suggests that consumers are not fully rational (or boundedly rational). Heidhues and Kőszegi [12] first introduced consumer loss aversion into the context of monopoly pricing and competitive pricing. Zhou [13] also found that loss aversion can reduce market competition by driving consumers to choose the price of a competitor's product in the market as the reference price when making a purchase decision in the model. The selection of reference prices in our article continues this hypothesis. Rosato [14], on the contrary, considered the strategies of manufacturers that sell multiproduct substitutes when consumers are loss averse. Scholars such as Schweitzer and Cachon [15], Liu et al. [16], and Nagarajan and Shechter [17] extended the newsvendor model based on the prospect theory to analyze the strategy formulation of loss-averse decision makers. Wang [18] further developed a newsvendor model to study a competitive market with multiple loss-averse retailers. Liu et al. [19] and Qiu et al. [20] studied a loss-averse newsvendor problem with reference dependence, while Zhou et al. [21] compared the impact of static loss-averse behaviors and dynamic loss-averse behaviors of retailers with demand uncertainty on the decisions and utilities of the supply chain. In this article, we consider both reference dependency and loss aversion of consumers.

The article is also related to the stream of research on supply chain coordination. Wang and Webster [22] examined the mitigating effect of gain/loss-sharing-and-buy-back contracts on the loss-aversion effect and the manufacturer's formulation of its contract with the retailer to coordinate the supply chain in a decentralized supply chain model consisting of a risk-neutral manufacturer and a loss-averse retailer. Chen et al. [23] compared the difference in decision-making between a loss-averse and a risk-neutral retailer in a supply chain model with short life-cycle products and analyzed the supply chain coordination problem in the presence of a loss-averse retailer. Hu et al. [24] found that the formulation of revenue-sharing contracts in a three-echelon supply chain model with a loss-averse retailer can achieve a Pareto improvement. Du et al. [25], who considered both suppliers with yield randomness and retailer with demand uncertainty loss aversion, derived the optimal strategy and illustrated the effect of loss aversion and yield randomness on supply chain performance. Liu et al.

[26] designed a contract that combined buyback and quantity flexibility to coordinate the supply chain with loss-averse retailers. Xie et al. [27] investigated a single-period two-echelon supply chain where the loss-averse retailer's marketing efforts influence the final market demand. In the scenario of random production and demand, Yueli et al. [28] researched the supply chain coordination with capital constraint and the loss-averse retailer. Some literature focused on the coordination of a dual-channel supply chain under the condition of loss aversion. Huang et al. [29] proposed a combined contract consisting of option and cost-sharing to achieve supply chain coordination and Pareto-improvement in a model with a loss-averse manufacturer and a risk-neutral retailer.

With the development of the Internet economy, a growing volume of literature extends supply chain issues to online channels. Shi et al. [30] examined the impact of different return strategies in a dual-channel supply chain model. Liu et al. [31] modeled a dual-channel supply chain with loss-averse consumers and classified products into basic products and luxury goods to determine the optimal price strategy. Tian et al. [32] focused on a dual-channel supply chain's pricing and channel differentiation strategy. Many scholars have considered additional factors in supply chain design. Lotfi et al. [33] reduced the costs of high-demand supply chains by establishing blockchain technology for transactions with cryptocurrency. Goli et al. [34] considered fuzzy uncertainty in the multi-objective, multi-product, and multi-period closed-loop supply chain network design and optimized the physical and financial flow in the supply chain. Alinezhad et al. [35] focused on the sustainability issues in a closed-loop supply chain network under uncertain conditions based on fuzzy theory. Lotfi et al. [36] applied hybrid fuzzy and data-driven robust optimization in designing resilience and sustainable healthcare supply chain with a vendor-managed inventory approach to tackle uncertainty and disruption.

2.1. Research Gap. According to the abovementioned studies, a large body of previous literature on the effect of vertical restraints assumes that consumers are perfectly rational. Unlike the traditional vertical restraint model, this article assumes that one fraction of consumers consists of loyal consumers of offline shops and that the other fraction is reference-dependent and then compares the competitive situation under the vertical decentralization structure and the vertical restraint structure. This article also investigates the theoretical mechanism of vertical restraints imposed by manufacturers, while, considering that partial consumers are loss averse to provide theoretical support for relevant antitrust cases. We indicate the similarities and differences between some of the relevant literature and this artical in Table 1.

Within the theoretical framework, some novel results are obtained. In the case of vertical restraints, manufacturers have an incentive to maintain a certain level of price gap to stimulate sales in the online channel. Although offline prices increase under vertical restraints, the latter eliminates the two-part markup, reduces average prices, and increases the total sales, which thereby improves social welfare. Hence, by relaxing the standard assumption that consumers are rational, the model proposed in this article yields new economic insights into the competitive effect and anticompetitive effects of vertical restraints. For antitrust policies, this article suggests that when consumers are bounded rationally, manufacturers have a greater incentive to impose vertical restraints. This factor should be taken into consideration when dealing with related cases.

Our model step is shown in Figures 1 and 2.

3. Problem Statement

We consider a two-tier supply chain consisting of a single manufacturer and two downstream retailers: retailer 1 and retailer 2. Retailer 1 is brick-and-mortar and retailer 2 is online. Then, the two retailers compete on price. The bricks-and-mortar retailer is the price leader in the downstream market [37, 38] and has a pool of loyal consumers due to its reputation and history, whereas the online shop does not have loyal consumers but is able to attract some consumers who are more sensitive to the price gap and are loss averse. Such consumers will make purchases from the lower-priced retailer.

Therefore, we suppose that there are two types of consumers. The total number of consumers is normalized as follows. We assume that A-type consumers are loyal consumers who buy only from retailer 1, accounting for a proportion of λ of the total. B-type consumers are loss-averse consumers, accounting for a proportion of $1-\lambda$ of the total. B-type consumers make choices by comparing the two retailers' prices (see Figure3).

To define the research question and to facilitate the construction of the subsequent model, the following assumptions are made:

(1) In the process of the game, all participants are information-symmetric and risk neutral.

(2) The utility function of a representative A-type consumer is $U_A = v(q_A) - p_1 q_A$, where q_A is the quantity purchased by A-type consumers, $v(q_A)$ is the gross utility of A-type consumers, and p_1 is the price of retailer 1's product.

(3) Based on the loss-averse consumer utility function in the literature [12, 13], we assume that the utility function of a representative B-type consumer buying from retailer i is $U_{Bi} = v(q_{Bi}) - q_{Bi}p_i + \beta q_{Bi} \max\left\{p_j - p_i, 0\right\} - \beta_1 q_{Bi} \times \max\left\{p_i - p_j, 0\right\}$ $(i = 1, 2;\ i \neq j)$, where $0 < \beta < 1$ denotes the utility gain coefficient when the price of the product actually purchased by the consumer is lower than its psychological price point, $\beta_1 > \beta$ denotes the utility loss coefficient when the actual price of the product purchased by the consumer is higher than its psychological price point, and q_{Bi} denotes the quantity purchased by B-type consumers from retailer i. For the simplicity of analysis, we assume that loss-averse consumers choose to make purchases from the lower-priced retailer after comparing prices, and this assumption is

Table 1: Literature comparison.

Author	Year	Dual channel	Coordination	Consumer loss aversion	Manufacturer loss aversion	Retailer loss aversion	Impact on social welfare
Du et al.	2018	—	√	—	√	√	—
Zhou et al.	2018	—	—	—	—	√	—
Liu et al.	2019	√	√	√	—	—	—
Huang et al.	2019	—	√	—	√	—	—
Liu et al.	2020	—	√	—	—	√	—
Liu et al.	2020	—	—	—	—	√	—
Xie et al.	2021	—	√	—	—	√	—
Qiu et al.	2021	—	—	—	—	√	—
Tian et al.	2022	√	√	—	—	—	—
Yueli et al.	2022	—	√	—	—	√	—
This research	2022	√	√	√	—	—	√

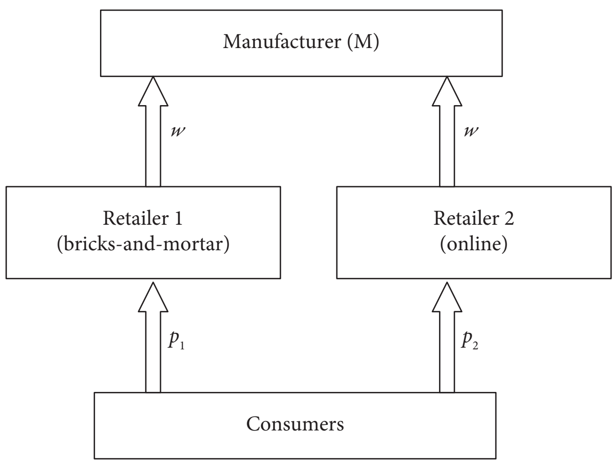

Figure 1: Decentralized model (p_1 and p_2 are set by retailers, respectively).

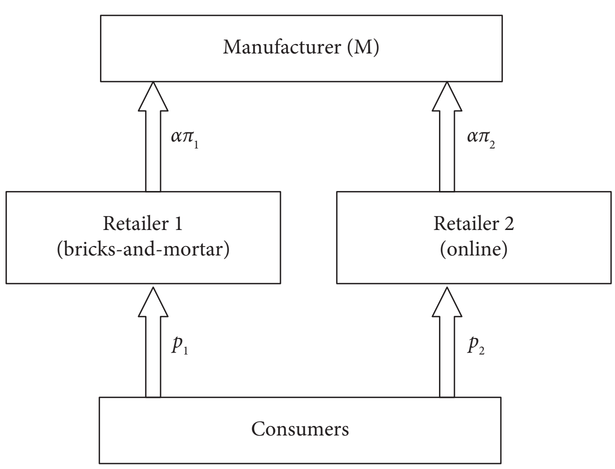

Figure 2: Centralized model (p_1 and p_2 are set by the manufacturers).

also consistent with what occurs in reality. Therefore, the last term of the utility function disappears.

(4) Assuming that $v(q) = [1 - (1-q)^2]/2$, the demand function of A-type consumers of retailer 1 can be obtained by a simple calculation, that is, $q_A = 1 - p_1$; the demand function of B-type consumers of retailer i is

$$q_{Bi} = \begin{cases} 1 - p_i + \beta\left(p_j - p_i\right), & \text{if } p_i < p_j, \\ \dfrac{(1-p_i)}{2}, & \text{if } p_i = p_j, \\ 0, & \text{if } p_i > p_j. \end{cases} \tag{1}$$

The demand of retailer 1 comes from both types of consumers, while that of retailer 2 comes solely from B-type consumers. The aggregate demand function for each of the two retailers can be obtained by summing the equations horizontally as $q_1 = \lambda q_A + (1-\lambda)q_{B1}$ and $q_2 = (1-\lambda)q_{B2}$.

The two following scenarios are considered:

(1) Separate operation (SP): the upstream manufacturer and downstream retailers make decisions individually.

(2) Vertically integrated operation (VI): the upstream manufacturer and downstream retailers coordinate and then make centralized decisions. The manufacturer can achieve maximum supply chain profits through vertical contracts, such as retail price maintenance and two-part tariffs.

The notations used in this article are described in Table 2.

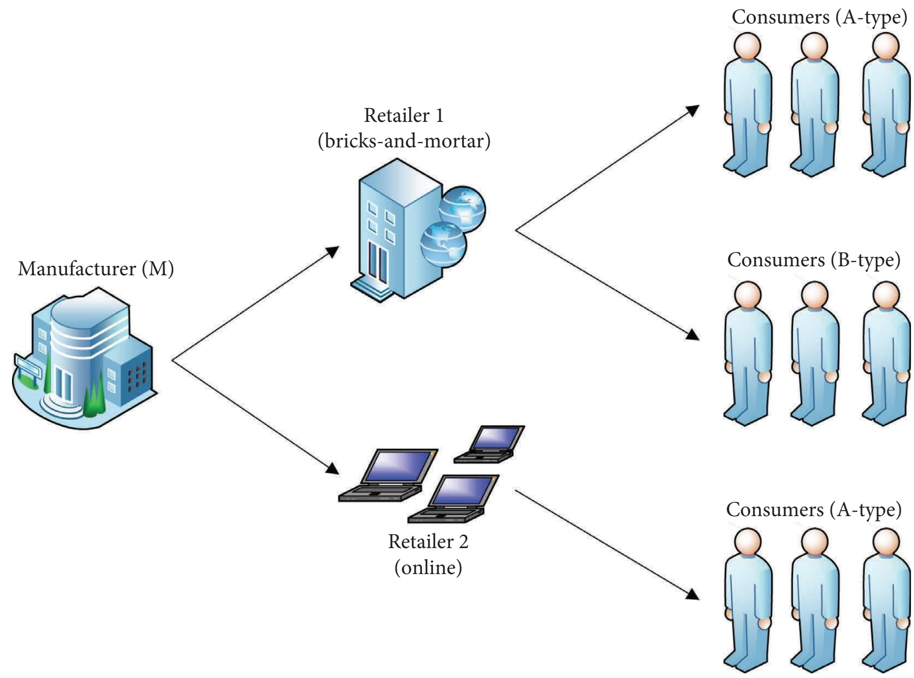

Figure 3: Diagram of the model structure.

Table 2: Summary of notations.

Notations	Definition
Indices	
A	Retailer 1's loyal consumers
B	Loss-averse consumers
i, j	Represent retailers
SP	Separate operation model
VI	Vertically integrated operation model
Parameters	
λ	The proportion of A-type consumers
$1-\lambda$	The proportion of B-type consumers
U	Utility that a representative consumer derives from the product
v	Total utility that consumers derive from the product
q_A	Quantity purchased by A-type consumers
q_B	Quantity purchased by B-type consumers
q_1	Demand for retailer 1
q_2	Demand for retailer 2
β	Utility gain coefficient
β_1	Utility loss coefficient
α	The proportion of profit that the manufacturer can get from the vertical coordination chain
π_1	The profit of retailer 1 in SP
π_2	The profit of retailer 2 in SP
π_{vi}	The profit of the integrated manufacturer
π'_{vi}	The profit of the integrated manufacturer under $p_2 > p_1$
π''_{vi}	The profit of the integrated manufacturer under $p_2 = p_1$
π'''_{vi}	The profit of the integrated manufacturer under $p_2 < p_1$
Q^{VI}	Total sales in VI
Q^{SP}	Total sales in SP
CS^{VI}	Consumer surplus in VI
CS^{SP}	Consumer surplus in SP
Decision variables	
w	The wholesale price of the upstream manufacturer
p_1	Price set by retailer 1
p_2	Price set by retailer 2

3.1. Decentralized Decision-Making. In a decentralized decision-making situation, an upstream manufacturer first sets the wholesale price, and then, downstream retailers compete on price. In contrast to a traditional vertical restraint study, this article assumes that consumers will use the prices of other channels as their reference prices when making purchase decisions. This channel price gap will affect consumers' utility and purchase decisions as some consumers are loss averse. In this case, this article identifies another form of price externality, that is, an increase in the price of the higher-priced channel expands the price gap between the two channels, thereby increasing the efficiency of the lower-priced channel. At the end of this section, we present a detailed analysis of this externality and its impact on competition.

In the first stage, the manufacturer with zero marginal cost sets a uniform wholesale price w $(0 < w < 1)$ of the product for both retailers; in the second stage, retailer 1 sets price p_1 after observing the wholesale price of the product; in the third stage, retailer 2 sets price p_2 after observing the wholesale price and retailer 1's price. We solve the subgame perfect Nash equilibrium (SPNE) of the model by backward induction.

In the third stage, given the upstream manufacturer's wholesale price w and retailer 1's price p_1, retailer 2's profit function is expressed as

$$\pi_2 = \begin{cases} (p_2 - w)(1-\lambda)(1 - p_2 + \beta(p_1 - p_2)), & \text{if } p_2 < p_1, \\ (p_2 - w)(1-\lambda)(1-p_2)/2, & \text{if } p_2 = p_1, \\ 0, & \text{if } p_2 > p_1. \end{cases} \quad (2)$$

Depending on the profit function of retailer 2, we must analyze it from several perspectives. First, we assume that, given p_1, retailer 2 considers the case of pricing $p_2 < p_1$ with a profit function that needs to be optimized as $\max_{p_2} \pi_2 = (p_2 - w)(1-\lambda)(1 - p_2 + \beta(p_1 - p_2))$. By solving the first-order condition, we obtain $p_2 = (1 + \beta p_1 + (1+\beta)w)/(2(1+\beta))$. Since $p_2 < p_1$ holds, so we can obtain $p_1 > (1 + (1+\beta)w)/(2+\beta)$; at this point, the profit of retailer 2 is $\pi_2 = ((1-\lambda)(1 - w + \beta(p_1 - w))^2)/(4(1+\beta))$.

When $p_1 \leq (1 + (1+\beta)w)/(2+\beta)$, there are two pricing strategies for retailer 2. If the price is set at $p_2 = p_1$, then the profit it will earn is $\pi_2(p_1, w) = (p_1 - w)(1-p_1)(1-\lambda)/2$, while if the price is set at $p_2 = p_1 - \varepsilon$ (where ε is an arbitrarily small constant), retailer 2 will be able to capture the market of loss-averse consumers and earn a profit of $\pi_2(p_1, w) \approx (1-\lambda)(p_1 - w)(1-p_1)$. Obviously, retailer 2 will set the price as $p_2 = p_1 - \varepsilon$.

Therefore, retailer 2's pricing strategy is

$$p_2 = \begin{cases} \dfrac{1 + \beta p_1 + (1+\beta)w}{2(1+\beta)}, \text{if } p_1 > \dfrac{1 + (1+\beta)w}{2+\beta}, \\ p_1 - \varepsilon, \text{if } p_1 \leq \dfrac{1 + (1+\beta)w}{2+\beta}. \end{cases} \quad (3)$$

The profit function of retailer 2 is

$$\pi_2 = \begin{cases} \dfrac{(1-\lambda)(1 - w + \beta(p_1 - w))^2}{4(1+\beta)}, & \text{if } p_1 > \dfrac{1 + (1+\beta)w}{2+\beta}, \\ (p_1 - w)(1-\lambda)(1-p_1), & \text{if } p_1 \leq \dfrac{1 + (1+\beta)w}{2+\beta}. \end{cases} \quad (4)$$

In the second stage, retailer 1 with rational expectations recognizes that in the absence of vertical restraints, regardless of its pricing $p_1 > (1 + (1+\beta)w)/(2+\beta)$ or $p_1 \leq (1 + (1+\beta)w)/(2+\beta)$, attracting B-type consumers is impossible; then, its profits can only come from the consumption of loyal consumers. Retailer 1's profit function is $\pi_1(w) = \lambda(1-p_1)(p_1 - w)$; it is easy to use the first-order conditions to find the optimal pricing of retailer 1 in the second stage, $p_1 = (1+w)/2$. Then, the sales of retailer 1 at this time are $q_1 = (1-w)\lambda/2$, and its profit is $\pi_1 = (1-w)^2\lambda/4$. Thus, we know that $p_1 > (1 + (1+\beta)w)/(2+\beta)$. Bringing p_1 into the equilibrium solution in the third stage, we can obtain $p_2 = (2 + \beta + (2+3\beta)w)/(4(1+\beta))$ and $q_2 = (1-\lambda)(2+\beta)(1-w)/4$; therefore, the profit of retailer 2 is $\pi_2 = (2+\beta)^2(1-\lambda)(1-w)^2/16$.

In the first stage, the upstream manufacturer chooses the wholesale price to maximize its profit, thus its profit function is $\max_{w} w(q_1 + q_2)$. Solving this maximization problem after introducing the results obtained above yields the detailed form. From this, we can obtain Proposition 1.

Proposition 1. *In the case of decentralized decision-making, the manufacturer's wholesale price is $w = 1/2$ in the equilibrium; the retailers' pricing and sales are $p_1 = 3/4$, $p_2 = (6+5\beta)/(8+8\beta)$, $q_1 = \lambda/4$, and $q_2 = (2+\beta)(1-\lambda)/8$ in the equilibrium.*

When the upstream and downstream firms make decisions separately, the offline shop and the online shop will set different prices, thus serving different types of consumers. The offline shops target and price for their loyal consumers to maximize profits.

The game and equilibrium analysis are under separate operation, and thus, they are the basis for analyzing the competitive effects of vertical restraints. When there are no vertical restraints, online shops effectively exploit the prices of offline shops to constitute the price gap, thus promoting loss-averse consumer spending. This channel price gap externality is internalized in the presence of vertical restraints so that manufacturers have an incentive to exploit this consumer psychology to stimulate sales, which is a direct incentive for upstream manufacturers to impose vertical restraints that has not been considered in the previous literature.

3.2. Centralized Decision-Making. Under centralized decision-making, all supply chain members attempt to maximize overall profits, which is equivalent to vertically integrating upstream manufacturers with downstream retailers and online shops. However, there are still two sales channels, namely, offline shops and online shops. In fact, manufacturers can achieve the effect of vertical integration with various vertical restraint tools. The profit function of the integrated firm is $\pi_{vi} = p_1 q_1 + p_2 q_2$. The firm needs to make decisions on both p_1 and p_2, and since the channel through which B-type consumers buy depends on which channel has a lower price, it needs to be analyzed in three cases according to the magnitude of p_1 and p_2.

(1) When $p_2 > p_1$, both types of consumers purchase in the offline shop, $q_1 = 1 - p_1 + (1-\lambda)\beta(p_2 - p_1)$ and $q_2 = 0$; therefore, the profit of the integrated manufacturer is $\pi_{vi} = p_1(1 - p_1 + (1-\lambda)\beta(p_2 - p_1))$. It is easy to obtain the price $p_1 = (1 + \beta(1-\lambda)p_2)/(2 + 2\beta(1-\lambda))$ in equilibrium using the first-order condition $\partial\pi_{vi}/\partial p_1$. In addition, we find that $\partial\pi_{vi}/\partial p_1 = p_1(1-\lambda)\beta > 0$. This shows that although there are no sales in channel 2 at this time, increasing the pricing in channel 2 can enhance the pricing in channel 1 and thus improve the total profit. In reality, the cost of maintaining a retail outlet is high, and manufacturers typically offer official websites to provide reference prices, publish suggested retail prices, or open direct sales on the Internet to make consumers use this price as a reference price, thus further promoting the demand for offline retailers.

According to the assumptions of the basic model, $p_2 \in [0,1]$, so $p_2 = 1$; thus, we can obtain the equilibrium solution when $p_2 > p_1$:

$$p_1 = \frac{1+\beta(1-\lambda)}{2+2\beta(1-\lambda)} = \frac{1}{2},$$
$$q_1 = 1 - p_1 + (1-\lambda)\beta(p_2 - p_1) = \frac{1+\beta(1-\lambda)}{2}, \tag{5}$$
$$\pi'_{vi} = (p_1 - c)q_1 = \frac{1+\beta(1-\lambda)}{4}.$$

(2) When $p_1 = p_2$, the offline shop will share B-type consumers equally with the online shop, so the demands of the integrated manufacturer are $q_1 = \lambda(1-p_1) + (1-\lambda)(1-p_1)/2$ and $q_2 = (1-\lambda)(1-p_2)/2$. The manufacturer's profit maximization problem is

$$\max_{p_1,p_2} p_1\left(\lambda(1-p_1) + \frac{(1-\lambda)(1-p_1)}{2}\right) + \frac{p_2(1-\lambda)(1-p_2)}{2} \tag{6}$$
$$\text{s.t. } p_1 = p_2.$$

By solving this maximization problem, we obtain $p_1 = p_2 = 1/2$. Thus, in this case, the manufacturer's profit is $\pi''_{vi} = 1/4$.

(3) When $p_2 < p_1$, B-type consumers all purchase in the online shop. The demands of the integrated manufacturer are $q_1 = \lambda(1-p_1)$ and $q_2 = (1-\lambda)((1-p_2) + \beta(p_1 - p_2))$. The profit function is $p_1\lambda(1-p_1) + p_2(1-\lambda)(1-p_2+\beta(p_1-p_2))$, and the first-order conditions are $\lambda(1-2p_1) + \beta p_2(1-\lambda) = 0$ and $(1-\lambda)(1-p_2+\beta(p_1-p_2) - (1+\beta)p_2) = 0$. By solving the conditions, we obtain $p_1 = (2\lambda + \beta(1+\lambda))/((2+\beta^2)\lambda - \beta^2)$ and $p_2 = ((2+\beta)\lambda)/((2+\beta^2)\lambda - \beta^2)$. The price gap between the two channels is $p_1 - p_2 = \beta/((2+\beta^2)\lambda - \beta^2) > 0$, satisfying the assumption. We can calculate the manufacturer's profit in this case as $\pi'''_{vi} = (1+\beta)\lambda/((2+\beta^2)\lambda - \beta^2)$.

By a simple calculation, we find that $\pi'_{vi} > \pi''_{vi}$. Comparing π'''_{vi} and π'_{vi} indicates that in the range of $\beta \in [0,1]$ and $\lambda \in [\beta^2/(2+\beta)^2, (\beta+\beta^2)/(2+\beta)^2]$, we have $\pi'''_{vi} > \pi'_{vi}$; in other ranges, we have $\pi'''_{vi} < \pi'_{vi}$. Therefore, when the relationship between the loss-aversion coefficient and the proportion of loyal consumers is in the range of $\beta \in [0,1]$ and $\lambda \in [\beta^2/(2+\beta)^2, (\beta+\beta^2)/(2+\beta)^2]$, a vertically integrated manufacturer will choose to set $p_2 < p_1$, thereby maintaining high prices for retailer 1 with loyal consumers and thus earning high profits from loyal consumers, and inducing price-sensitive consumers to purchase from retailer 2. When the relationship is not in this range, the vertically integrated manufacturer uses retailer 2 as the "price benchmark" to motivate consumers to purchase from retailer 1. This leads to the Proposition 2.

Proposition 2. *The pricing strategy of the vertically integrated manufacturer depends on the relationship between the loss-aversion coefficient and the proportion of loyal consumers. Thus, when* $\beta \in [0,1]$ *and* $\lambda \in [\beta^2/(2+\beta)^2, (\beta+\beta^2)/(2+\beta)^2]$, *the price will be set at* $p_2 < p_1$, *and A-type consumers and B-type consumers will purchase from the offline shop and the online shop, respectively, in which case the two channels' equilibrium prices will be* $p_1 = (2\lambda + \beta(1+\lambda))/((2+\beta)^2\lambda - \beta^2)$ *and* $p_2 = (2+\beta)\lambda/((2+\beta)^2\lambda - \beta^2)$, *and the equilibrium profit will be* $\pi_{vi} = \pi'''_{vi} = (1+\beta)\lambda/((2+\beta)^2\lambda - \beta^2)$. *In other ranges, the price will be set at* $p_2 > p_1$, *and A-type consumers and B-type consumers will purchase from the offline shop, in which case the two channels' equilibrium prices will be* $p_1 = 1/2$ *and* $p_2 = 1$, *and the equilibrium profit will be* $\pi_{vi} = \pi'_{vi} = (1+\beta(1-\lambda))/4$.

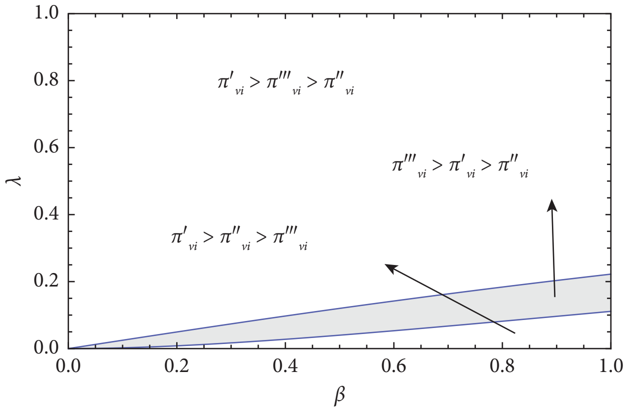

Figure 4: Equilibrium profit under centralized decision-making.

Figure 4 intuitively displays the equilibrium described in Proposition 2. In the blank area, the price is set at $p_2 > p_1$, and both A-type consumers and B-type consumers will purchase from the offline shop. The manufacturer has incentives to set a higher price for the offline shop, so as to stimulate online sales.

4. Results

When upstream manufacturers impose vertical restraints on downstream retailers, the equilibrium price and demand for the product in the downstream market becomes equal to the outcome under integration, which implies the disappearance of the double markup and the fact that the total profits of all firms are greater than the total profits of firms in the decentralized case. However, as vertical restraints affect consumer surplus, social welfare requires further analysis.

4.1. Comparison and Discussion. First, we assess the difference in the final market price of the product in the range of $\beta \in [0,1]$ and $\lambda \notin \in [\beta^2/(2+\beta)^2, (\beta+\beta^2)/(2+\beta)^2]$ (the first equilibrium of the centralized decision) in the two cases (the superscript VI indicates the solution under integration and SP indicates the solution when operating separately; these superscripts denote the same hereafter):

$$\Delta p_1 = p_1^{\mathrm{VI}} - p_1^{\mathrm{SP}} = -\frac{1}{4} < 0, \tag{7}$$

$$\Delta p_2 = p_2^{\mathrm{VI}} - p_2^{\mathrm{SP}} = \frac{2+3\beta}{8+8\beta} > 0. \tag{8}$$

From equations (7) and (8), we see that when the proportion of loyal consumers λ is too small or too large, the integrated manufacturer will abandon the online channel and use it as a price benchmark to stimulate offline sales by using the high price of the online channel.

Combining equations (7) and (8) yields

$$\left|p_1 - p_2\right|^{\mathrm{VI}} - \left|p_1 - p_2\right|^{\mathrm{SP}} = \frac{4+3\beta}{8+8\beta} > 0. \tag{9}$$

In the case of vertical restraints or vertical integration, the price gap between channels is expanded to promote consumer purchases. This gap decreases as the loss-aversion coefficient increases.

In the range of $\beta \in [0,1]$ and $\lambda \in [\beta^2/(2+\beta)^2, (\beta+\beta^2)/(2+\beta)^2]$, the gap between the final market prices of the two products is

$$\Delta p_1 = p_1^{\mathrm{VI}} - p_1^{\mathrm{SP}} = \frac{2\lambda + \beta(1+\lambda)}{(2+\beta)^2\lambda - \beta^2} - \frac{6+5\beta}{8+8\beta} > 0. \tag{10}$$

The reason that the integrated manufacturer will set higher prices in the offline channel is that with vertical integration, competition between the two channels is internalized, so setting high prices in the online channel can deprive loyal consumers of surplus and stimulate sales in the offline channel:

$$\Delta p_2 = p_2^{\mathrm{VI}} - p_2^{\mathrm{SP}} = \frac{\lambda(2+\beta)}{(2+\beta)^2\lambda - \beta^2} - \frac{3}{4}. \tag{11}$$

The signs of equation (11) depends on the specific range of λ. When $\lambda \in [\beta^2/(2+\beta), 3\beta^2/((2+\beta)-\beta^2)]$, we have $\Delta p_2 > 0$; when $\lambda \in [3\beta^2/((2+\beta)-\beta^2), (\beta+\beta^2)/(2+\beta)^2]$, we have $\Delta p_2 < 0$. The reason for this is that when λ is small, the integrated manufacturer values the benefits generated by the online channel more and sets the online price p_1 at a higher level, which in turn drives up p_2; as λ increases, p_1 will gradually decrease, while driving down p_2 and eventually yielding the case $\Delta p_2 < 0$.

By combining equations (10) and (11), we get

$$\left|p_1 - p_2\right|^{\mathrm{VI}} - \left|p_1 - p_2\right|^{\mathrm{SP}} = \frac{\beta\left(\lambda(2+\beta)^2 + 8(1+\beta) - \beta^2\right)}{8(1+\beta)\left(\lambda(2+\beta)^2 - \beta^2\right)} > 0. \tag{12}$$

In the equilibrium of vertical integration with $p_2 < p_1$, the price gap between channels is expanded to promote consumer purchases; however, unlike the equilibrium with $p_2 > p_1$, the channel price gap increases with the loss-aversion coefficient and decreases with the proportion of loyal consumers in the equilibrium with $p_2 < p_1$.

Proposition 3. *Compared to the market equilibrium under separate operation, integrated manufacturers have an incentive to expand the price gap between the two channels in either the $p_2 > p_1$ or the $p_2 < p_1$ equilibrium, thus promoting sales in the "primary" channel in the integrated equilibrium with $p_2 > p_1$, the primary sales channel is the offline channel, where the channel price gap decreases as the sensitivity to loss aversion increases; in the integrated equilibrium with $p_2 < p_1$, the primary sales channel is the online channel, where the channel price gap increases as the sensitivity to loss aversion increases.*

Second, the total sales Q^{VI} and Q^{SP} in both cases are compared to investigate the stimulative effect of the strategic channel price gap on total sales. In the integration equilibrium with $p_2 > p_1$, the difference in sales compared to the separation equilibrium is

$$Q^{VI} - Q^{SP} = \frac{(2 + 3\beta(1 - \lambda))}{8} > 0. \tag{13}$$

The total sales differential is positive, and we know that $\partial\Delta Q/\partial\beta > 0$ and $\partial\Delta Q/\partial\lambda < 0$:in the integrated equilibrium with $p_2 > p_1$, the online channel sales are zero and used solely as a "price benchmark," so with an increase in the loss-aversion coefficient, the upstream manufacturer stimulates consumption by expanding the strategic channel price gap and thus exploiting consumers' loss aversion to increase the total sales and thereby enhancing the total channel profit. With an increase in the proportion of loyal consumers λ, the "price benchmark" role of the online channel weakens thus reducing the revenue expansion effect generated by expanding the channel price gap, so the sales differential decreases as the proportion of loyal consumers λ increases.

In the integration equilibrium with $p_2 < p_1$, the difference in sales compared to the separation equilibrium is

$$Q^{VI} - Q^{SP} = \frac{8\lambda + \beta\left(\beta(2 + \beta) + 4\lambda - 2\beta\lambda(3 + \beta) + (2 + \beta)^2\lambda^2\right)}{8(2 + \beta)^2\lambda - 8\beta^2} > 0. \tag{14}$$

The total sales differential remains positive, meaning that the total sales are always higher with vertical restraints. At this point, $\partial\Delta Q/\partial\beta > 0$ and $\partial\Delta Q/\partial\lambda < 0$: In the integration equilibrium with $p_2 < p_1$, the online channel will set a lower price, and with the enhancement of the loss-aversion coefficient, the additional utility from the high price of the offline channel will be strengthened, thus more strongly stimulating the sales of the offline channel, so $\partial\Delta Q/\partial\beta > 0$; as the proportion of loyal consumers λ increases, fewer consumers receive the additional utility of the "price benchmark," thus limiting the total demand of the integrated manufacturer, so the sales differential decreases as the proportion of loyal consumers increases.

4.1.1. Welfare Analysis. From equations (7) and (8), it can be seen that in the equilibrium of vertical restraints with $p_2 > p_1$, the price of the offline shop decreases and the price of the online shop increases, so all consumers buy from the offline shop. Since the price of the offline shop is also lower than the price of the online shop in the separating equilibrium, the demand for all types of consumers is raised, and the total consumer utility is enhanced.

Equations (10) and (11) indicate that in the equilibrium of vertical restraints with $p_2 < p_1$, the price of the offline shop increases, and there is uncertainty about the price variation of the online shop. In this case, loyal consumers necessarily lose their surplus, but there is a uncertainty in the change of loss-averse consumers' surplus. When $\lambda \in [\beta^2/(2 + \beta), 3\beta^2/((2 + \beta) - \beta^2)]$ and $\Delta p_2 > 0$, but $\Delta p_1 > 0$ then, it will provide an additional utility to loss-averse consumers, so the surplus change for loss-averse consumers depends on the net effect of price changes in both channels. When $\lambda \in [3\beta^2/((2 + \beta) - \beta^2), (\beta + \beta^2)/(2 + \beta)^2$, and $\Delta p_2 < 0$, the superposition of the utility gains from $\Delta p_1 > 0$, and we obtain that loss-averse consumers' surplus is improved. To further compare consumer surplus in the equilibrium of vertical restraint case with $p_2 < p_1$ and in the separate operation equilibrium, the expression for consumer surplus can be shown as

$$CS^{VI} = \frac{\lambda(1 + \beta)^2\left(4\lambda + \beta^2(1 - \lambda)\right)}{2\left(\lambda(\beta + 2)^2 - \beta^2\right)^2}, \tag{15}$$

$$CS^{SP} = \frac{\lambda\left(8 + 4\beta + \beta^2\right)}{128}. \tag{16}$$

Equation (15) minus equation (16) shows that the consumer surplus differential under vertical restraints and under separate operation is always positive within the parameter.

$$\Delta CS = CS^{VI} - CS^{SP} > 0. \tag{17}$$

Equation (17) shows that consumer surplus is always larger under the imposition of vertical restraints, meaning that the vertical restraint behavior of the upstream manufacturer increases consumer welfare. This leads to Proposition 4.

Proposition 4. *Compared to the case of separate operations, consumer surplus increases when vertical restraints are imposed by upstream manufacturers in both cases. As the total profit of the firm increases, social welfare also increases.*

Proposition 4 shows that when consumers are able to derive utility from the price gap, consumer surplus is improved in the vertical restraint case when the upstream manufacturer endogenizes the channel price gap, thus allowing consumers to derive additional utility from the price gap. In addition, the pricing decision in the separate operation case is a subset of the pricing set in this case when vertical coordination is achieved. Therefore, the overall profits of firms must increase when vertical restraint coordination is achieved, and total social welfare is improved.

The equilibrium solutions and differentials of all variables under decentralized and centralized decision-making are given in Table 3.

In contrast to previous studies, this article demonstrates that if consumers exhibit loss aversion under bounded rationality, the implementation of vertical restraints is beneficial to social welfare. Thus, the antitrust authority, which seeks to maximize social welfare, should not adopt the "per se illegal rule" on the vertical restraint behavior of firms but rather use the "rule of reason" to conduct a comprehensive analysis of market performance.

4.2. Sensitivity Analysis. To verify the abovementioned theoretical model conclusion more intuitively, parameters are established to verify the model numerically.

In the equilibrium of vertical restraints with $p_2 > p_1$, the manufacturer's online channel is used solely as the "price benchmark." $\lambda = 2/5$ is set to compare the change in the channel price gap, overall profit, and consumer surplus. The variation in the channel price gap is shown in Figure 5, and the channel price gap in the equilibrium of vertical restraints

Table 3: Equilibrium solutions under decentralized and centralized decision-making and comparison.

Variable	Decentralized (SP)	Centralized 1 (VI) ($p_2 > p_1$)	Centralized 2 (VI) ($p_2 < p_1$)	Differential 1	Differential 2
Price					
Offline shop p_1	$3/4$	$1/2$	$(2\lambda + \beta(1+\lambda))/((2+\beta)^2\lambda - \beta^2)$	−	+
Online shop p_2	$(6+5\beta)/(8+8\beta)$	1	$((2+\beta)\lambda)/((2+\beta)^2\lambda - \beta^2)$	+	−
Price gap $\|p_1 - p_2\|$	$\beta/(8+8\beta)$	$1/2$	$\beta/((2+\beta)^2\lambda - \beta^2)$	+	+
Demand					
Offline shop q_1	$\lambda/4$	$(1+\beta(1-\lambda))/2$	$(\lambda - \lambda(\beta + (2+\beta)\lambda))/((2+\beta)^2\lambda - \beta^2)$	+	−
Online shop q_2	$((2+\beta)(1-\lambda))/8$	0	$(\lambda(1-\lambda)(2+3\beta+\beta^2))/((2+\beta)^2\lambda - \beta^2)$	−	+
Total demand Q	$(2+\beta-\beta\lambda)/8$	$(1+\beta(1-\lambda))/2$	$(2\lambda(1+\beta))/((2+\beta)^2\lambda - \beta^2)$	+	+
Total profit	$(12+4\beta(4-\lambda)+5\beta^2(1-\lambda))/(64(1+\beta))$	$(1+\beta(1-\lambda))/4$	$((1+\beta)\lambda)/((2+\beta)^2\lambda - \beta^2)$	+	+
Consumer surplus	$(4+\beta(4+\beta)(1-\lambda))/128$	$(\beta(\beta+2)(1-\lambda)+1)/8$	$(\lambda(1+\beta^2(4\lambda+\beta^2(1-\lambda)))/(2(\lambda(\beta+2(\beta)^2-\beta^2)^2)$	+	+

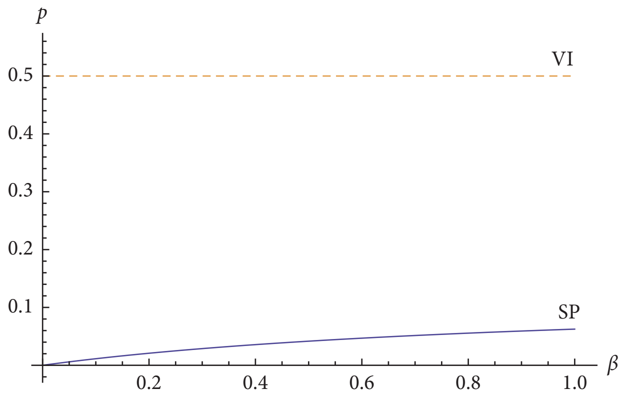

Figure 5: Channel price gap comparison (p2>p1).

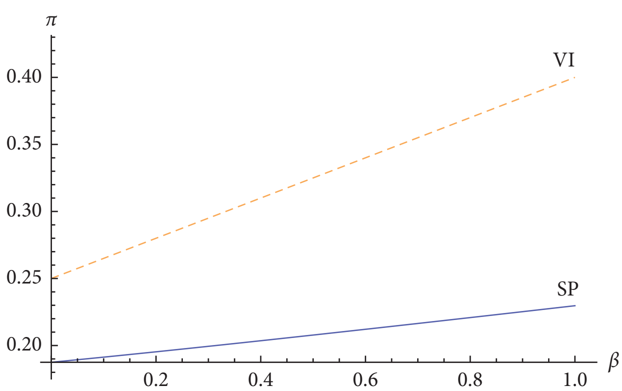

Figure 6: Profit comparison(p2>p1).

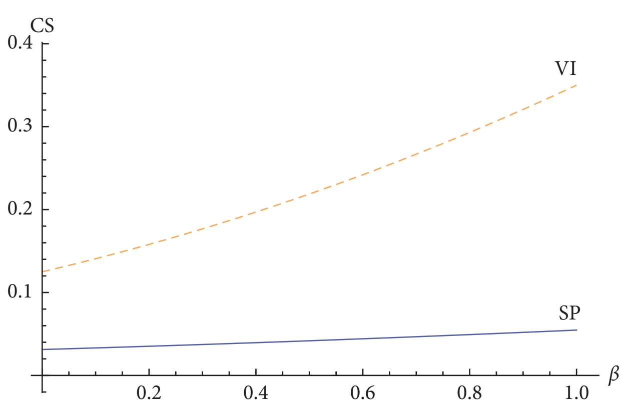

Figure 7: Consumer surplus comparison(p2>p1).

with $p_2 > p_1$ is larger than that in the separated equilibrium, and this price gap decreases with an increase in the loss-aversion coefficient.

Figure 6 shows an increase in the overall profit with vertical restraints, and the profit under vertical restraints is significantly higher than that in the separation equilibrium, and the profit difference increases with the increase in the loss-aversion coefficient β. This indicates that the "price benchmark" role of the offline channel increases with the increase in the loss-aversion coefficient β.

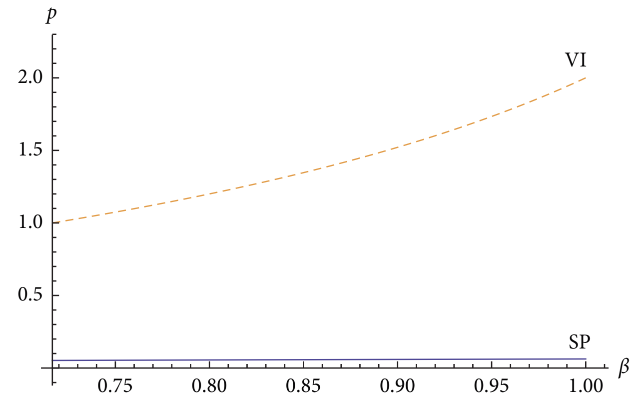

Figure 8: Channel price gap comparison(p2<p1).

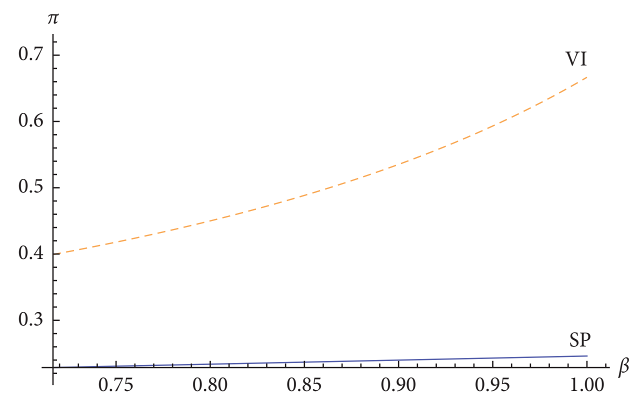

Figure 9: Profit comparison(p2<p1).

Figure 7 shows the increase in consumer surplus due to vertical restraints, and the consumer surplus is significantly higher under vertical restraints than under the separating equilibrium, and the difference in consumer surplus increases with the increase in the loss-aversion coefficient β. This indicates that the role of the "price benchmark" is enhanced with the increase in β, thus increasing the overall profit and consumer surplus.

In the equilibrium of vertical restraints with $p_2 < p_1$, the manufacturer's offline channel is used to extract loyal consumer surplus, and the online channel is used to attract loss-averse consumers. By setting $\lambda = 1/6$, we compared the changes in the channel price gap, overall profit, and consumer surplus within the parameter range in the equilibrium of vertical restraints with $p_2 < p_1$. The change in the channel price gap is shown in Figure 8, and the channel price gap under the vertical restraint equilibrium is larger than that under the separated equilibrium; unlike the vertical equilibrium with $p_2 > p_1$, the difference between the two equilibrium expands with the increase in the loss-aversion coefficient β. The manufacturer that implements vertical restraints can sell using both channels, and they can enhance the purchase of disloyal consumers by increasing the price gap.

Figure 9 demonstrates the enhancement of overall profits due to vertical restraints, and profits under vertical restraints are significantly higher than those under the separation

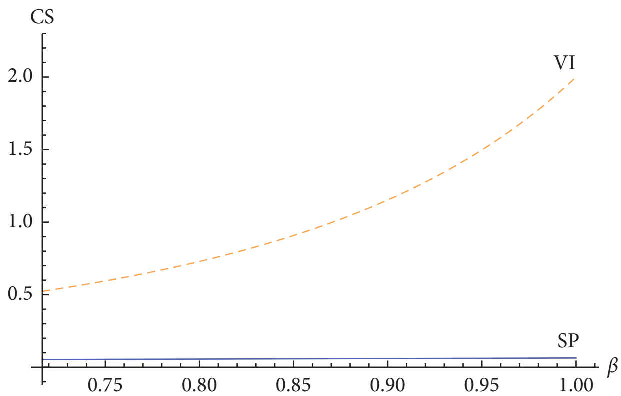

Figure 10: Consumer surplus comparison(p2<p1).

equilibrium, and the profit differential increases with the loss-aversion coefficient β; the profit differential in the equilibrium with $p_2 < p_1$ is greater than that in the equilibrium with $p_2 > p_1$ equilibrium because the two channels are used to serve different consumer types.

Figure 10 demonstrates the enhancement of consumer surplus due to vertical restraints, and consumer surplus under vertical restraints is significantly higher than that in the separated equilibrium, and the consumer surplus differential expands with the loss-aversion coefficient β. Again, because the two channels are used to serve different consumer types, the full use of the channel price gap leads to a significantly larger surplus differential under the equilibrium where $p_2 < p_1$ than under the equilibrium where $p_2 > p_1$.

5. Managerial Insights and Policy Implications

Under the influence of information technology, it has become more convenient for consumers to search and compare prices, so loss-averse consumers tend to look for the cheapest products. Moreover, retailers in online channels exploit this consumer psychology to prominently mark corresponding offline channels' prices on online sales pages for promotion. If the channel is not coordinated with vertical restraints, then this behavior is actually "free-riding" on the channel price gap. Online retailers use the price cues of offline shops to increase their consumers' psychological utility and thus promote product sales. On this basis, upstream manufacturers have an incentive to maximize total profits by internalizing the externalities of the channel price gap using vertical restraints such as resale price maintenance and two-part tariffs.

While manufacturers can use vertical restraints to internalize the effects of the channel price gap, their actions are prone to channel conflicts and related antitrust reviews if they do not pay attention to revenue sharing and specific measures for downstream retailers in their agreements. The Shanghai Municipal Development and Reform Commission's decided to impose administrative penalties on Chongqing Haier Home Appliance Sales Co., Ltd. Shanghai Branch for implementing minimum resale prices exactly because of complaints from Haier retailers. The "rule of reason" is applied to resale price maintenance in judicial practice. In recent years, resale price maintenance and other vertical restraint cases have become a major focus of Chinese antitrust authorities, so firms should be very cautious in using vertical restraints while recognizing the incentives behind them.

6. Conclusions

The main goal of this research study is to explain the phenomenon of online and offline price gaps and to present a mathematical framework for analyzing the effect of vertical restraints. This article investigates how firms use vertical restraints to endogenize the impact of the channel price gap on consumers when some consumers search for prices and exhibit loss aversion. Therefore, the main contribution of this article is to consider the role of consumers' bounded rationality in dual supply chain coordination. The comparative study also answers whether vertical restraints should be prohibited when consumers are loss averse.

The main results of this article are as follows:

(1) When the supply chain is not coordinated by the manufacturer, an online retailer can exploit consumers' loss aversion by using a higher offline price. The offline price acts as a reference price, and the channel price gap then offers extra utility to loss-averse consumers, thus stimulating sales in the online shop.

(2) When the supply chain is coordinated by a manufacturer, upstream manufacturers have an incentive to maximize total profits by internalizing the externalities of the channel price gap, using vertical restraints such as resale price maintenance and two-part tariffs. In this case, vertical restraints help reduce price gaps and increase sales.

(3) From the perspective of social welfare, the consumer surplus and total profits are significantly higher under vertical restraints. Therefore, when consumer loss aversion is considered, vertical restraint contracts are not anticompetitive, as found in previous studies.

While this article examines the effect of dual-channel coordination on market competition and social welfare when consumers are loss averse, it does not consider enough cases. There are several interesting topics for further research studies. The research can get closer to the real world by applying uncertainty in modeling [39, 40]. For example, the uncertainty of market demand or fuzzy network should be considered [36, 41], information asymmetry should be examined, and quality uncertainty and return policy cases should be explored. We also consider developing a dynamic model with interdependent demand [42, 43], and a stochastic model [44], which are worthy of future study.

Data Availability

The data used to support the findings of the study can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (no. 71803123).References

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