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ORIGINAL RESEARCH

Optimizing pricing and ordering strategies for new products in the presence of consumers with pre-purchase beliefs

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Abstract

The new retail era has dramatically altered consumer behavior, with more people now making purchases based on their pre-purchase beliefs about products, even if they lack prior experience with them. Pre-purchase beliefs represent the anticipated value consumers associate with buying a product or service. This study examines how such beliefs influence consumer purchasing decisions and, in turn, affect retailers' operational decisions and selling strategies. To achieve this, we create an analytical model that characterizes the consumer decision-making process driven by pre-purchase beliefs and has framed the problem of launching new products as a newsvendor problem. We determine the optimal pricing and ordering strategies for retailers and explored the most effective strategies for different consumer types. Our research indicates that deliberately emphasizing or downplaying product attributes can be more effective in pre-launch marketing than providing strictly accurate information. For value-for-money brands, it's advisable to adjust the operational strategy to "sell less but at a slightly higher price" as the new product struggles to meet consumer expectations. In markets with diverse consumer segments, retailers must accurately estimate the market sizes of each consumer type and anticipate their pre-purchase beliefs. The value consumers place on

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these beliefs, along with the market sizes of different consumer categories, play a pivotal role in strategy selection. In summary, this study offers valuable insights into the relationship between consumer purchasing behavior driven by pre-purchase beliefs and retailers' operational decisions and selling strategy choices.

Keywords Pre-purchase belief · Consumer purchasing driven by pre-purchase beliefs · Newsvendor model · New product

1 Introduction

The advent of online shopping has spurred a transformation in consumer purchasing behavior. Increasingly, individuals are willing to make purchases even in the absence of prior product experience or physical exposure. A recent survey found that a substantial 78% of online shoppers do not deem it necessary to physically inspect a product in a store before completing an online purchase.[1] This absence of direct product experience prior to purchase gives rise to pre-purchase beliefs, representing the desired valuation or expected worth of the product (Olson and Dover, 1979; Mellers et al., 1999). These pre-purchase beliefs exert a significant influence on consumer behavior and decision-making, shaping their anticipated actions and outcomes associated with the product (Bhattacherjee, 2001). In essence, pre-purchase beliefs emerge as a pivotal psychological factor governing individuals' economic choices.

In the contemporary consumer landscape, the sway of pre-purchase beliefs on purchasing decisions has gained considerable prominence. Several key factors contribute to this phenomenon. Firstly, the wealth of information available to consumers through online reviews and word-of-mouth has a substantial role in shaping their pre-purchase beliefs and expectations before any physical interaction with the product. Secondly, businesses invest substantial effort in advertising and marketing to influence consumer perceptions and expectations concerning the benefits and features of their offerings. Lastly, the overwhelming array of choices in the market has led to choice overload, prompting consumers to rely more on their pre-purchase expectations as a simplifying mechanism for the decision-making process. This trend is especially pronounced in the sales of new digital and technology products, where consumers heavily depend on their pre-purchase beliefs, influenced by information and promotional efforts, to assess the potential advantages and value of these innovations.

Moreover, the absence of prior product experience before purchase can result in a significant disparity between pre-purchase beliefs and the actual product value. This disparity poses a critical consideration for retailers as it can significantly affect consumer satisfaction and sales. In the business domain, when introducing new products, companies often employ diverse strategies to manage consumer pre-purchase beliefs. For example, companies like Callaway Golf and Apple employ advertising tools to foster high consumer expectations ahead of product release (Banerjee and Sarvary, 2009). Conversely, some firms choose to understate and overdeliver, intentionally lowering expectations to surpass consumer satisfaction, as exemplified by Toyota when introducing Lexus (Kopalle and Lehmann, 2006).

Understanding consumer prior beliefs is crucial when launching a new product. From a marketing perspective, studies such as Spreng et al. (1996) have suggested that prior beliefs, coupled with perceived performance, can evoke emotions after purchasing, leading to either satisfaction (when the product outperforms expectations) or dissatisfaction. This is explained by the expectation-confirmation theory. Several factors can influence con-

[1] Source: https://www.invespcro.com/blog/online-consumer-shopping-habits-behavior/.

sumers' pre-purchase beliefs, including product features, inventory availability, unknown attributes/outcomes, reservation utility (Kőszegi and Rabin, 2006), anticipated emotions (Mellers et al., 1999), and social comparison (Bearden and Rose, 1990). Nevertheless, the purchasing decisions made by consumers with pre-purchase beliefs have yet to undergo comprehensive analysis. Within the realms of operations and retailing, there remains a lack of clarity regarding the optimal responses that retailers should employ in light of consumers' pre-purchase beliefs. Additionally, there is uncertainty surrounding the most effective adjustments to retailing strategies aimed at catering to consumers possessing these pre-purchase beliefs, which we abbreviate as pre-belief consumers, especially in the context of prelaunch announcements. Therefore, the following interesting and unexplored questions remain.

- How do consumers' pre-purchase beliefs affect retailers' pricing and ordering decisions?
- How should retailers sell new products to consumers with pre-purchase beliefs?
- What is the optimal selling strategy across different consumer types?

This study seeks to address the aforementioned questions by focusing on the influence of consumers' pre-purchase beliefs on retailers' operational decisions and their choice of selling strategies. We accomplish this by employing analytical modeling techniques to illustrate the consumer buying decision process, specifically driven by pre-purchase beliefs. Additionally, we frame the challenge of launching new products as a newsvendor problem, enabling us to derive retailers' optimal responses to pricing and ordering decisions when dealing with consumers who hold pre-purchase beliefs. Furthermore, we investigate the most effective selling strategies across various consumer types and explore the impacts of consumer diversity on strategy selection.

Our research presents a pioneering effort in explicitly modeling purchasing decisions influenced by pre-purchase beliefs alone, as well as decisions shaped by both pre-purchase beliefs and consumer surplus. While previous studies (e.g., Burmester et al., 2015; Karle & Peitz, 2014) have acknowledged the significant influence of beliefs on consumer purchase decisions, they have not delved into the explicit modeling of the decision-making process. Moreover, our study contributes significantly by examining how retailers should respond when consumer buying decisions are increasingly motivated by pre-purchase beliefs, particularly from an operational perspective. To the best of our knowledge, this is the first study to consider consumer pre-purchase beliefs in the context of retailers' operational decisions and strategy selection.

Our research yields novel and critical managerial insights. Firstly, we discover that effectively managing and adjusting consumer pre-purchase beliefs regarding product value towards appropriate values can enhance retailers' profitability. Constantly raising or lowering consumers' expectations for new products is counterproductive. This suggests that strategically modulating consumer expectations in the pre-launch marketing process, whether by over- or understating product attributes, can be beneficial. Secondly, in cases where consumers' purchasing decisions are influenced by both pre-purchase belief and consumer surplus, pricing higher and ordering less can enhance retailer profitability, even if the new product falls short of consumers' pre-purchase beliefs. This implies that, particularly for value-for-money brands facing challenges in meeting consumer expectations, adapting the operational strategy to "sell less but at a slightly higher price" is the optimal approach. Thirdly, when catering to a market comprising diverse consumer segments, the value of pre-purchase belief and the market sizes of each consumer type become pivotal in selecting the most suitable selling strategy. Our findings emphasize the importance of precise estimation of market sizes for different consumer types and accurate prediction of consumer pre-purchase beliefs.

The remainder of this paper is organized as follows. In Sect. 2, we review the related literature. Section 3 introduces the problem settings and model formulations. Section 4 studies the optimal decisions when selling to consumers with pre-purchase beliefs. In Sect. 5, we study the retailer's optimal selling strategy. In Sect. 6, we explore the impact of consumer heterogeneity in pre-purchase beliefs and buying behaviors on the retailer's optimal selling strategy. Section 7 concludes the paper.

2 Literature review

In Sects. 2.1–2.3, we provide a succinct overview of the literature, focusing on three key areas: new product diffusion, consumer pre-purchase beliefs, and the newsvendor problem with consumer behavior. In Sect. 2.4, we establish our position within the existing literature.

2.1 New product diffusion

The literature on new product diffusion and development has been a subject of extensive examination from various perspectives. Past research in this domain has delved into multiple stages, encompassing product ideation, design, and supply chain optimization. In the following, we concisely review some recent works in the intersection between operations and marketing in the context of new product retailing.

A review by Rand and Stummer (2021) underscores the challenges associated with predicting the success of new product launches in today's intricate and unpredictable business landscape. The authors emphasize that traditional models, assuming rational behavior among market stakeholders, may no longer suffice. Instead, stakeholders' actions and reactions to others significantly influence their behavior, making accurate forecasting of new product diffusion a formidable task. To tackle this challenge, the study underscores the need for a deeper comprehension of consumer behavior in the realm of new product development. By gaining insights into consumer preferences, behaviors, and decision-making processes, companies can enhance their capacity to develop and successfully launch new products.

Recent studies have also concentrated on consumer behavior within the context of new product diffusion and development. In the presence of quality-learning consumers, Chen and Jiang (2021) examine how firms selling new non-durable experience goods can signal high quality to consumers through dynamic spot-pricing or price commitment. Additionally, Feldman et al. (2019) investigate the influence of social learning on new product design when consumers consult peer reviews before making purchase decisions. When dealing with strategic buying consumers, Liang et al. (2014) explore optimal product rollover strategies. Lobel et al. (2016) scrutinize the timing of new product version releases, while Yu et al. (2016) investigate the influence of consumer reviews on a firm's dynamic pricing strategy. Furthermore, Zhao and Stecke (2010) and Wu et al. (2021) delve into advanced selling strategies to maximize profits. Beyond consumer behavior, several studies have explored the impact of retailer behavior on new product retailing decisions. For instance, Choi (2018) investigate how the risk aversion of a retailer influences the process of new product selection and coordination within a fashion supply chain.

Recent studies have also shed light on the evolving role of consumers in the marketplace. No longer passive recipients of marketing messages, consumers have become active participants influenced by social networks and online communities. Ji et al. (2022) delve into the impact of social interaction features, such as word of mouth and observational learning, on consumers' purchase intentions, specifically within the context of live streaming commerce. They analyze the optimal pricing and quality decisions within this environment. Similarly, Giannakis et al. (2020) explore the influence of consumer emotions expressed through social media on all stages of new product development. The study investigates variations in consumer sentiments and underscores the importance of monitoring and understanding these emotions to effectively manage new product launches.

In addition to traditional research methods, big data has emerged as a crucial tool in aiding companies in uncovering valuable insights not easily revealed through conventional market research approaches. For instance, Zhan et al. (2018) investigate the role of big data in uncovering customers' unrecognized needs, shedding light on the potential of data analytics in identifying and addressing consumer preferences and demands that may not be explicitly expressed. Furthermore, Disch (2023) and Chatterjee (2023) specifically explore the utilization of external data in two areas: supplier selection and cost estimation for new product development.

In summary, recent studies in the field of new product diffusion and retailing have placed substantial emphasis on a comprehensive understanding of consumer behavior throughout the new product launch process. Additionally, these studies have underscored the dynamic nature of consumers' roles in the marketplace and the significance of developing strategies to respond to their behaviors.

2.2 Consumer pre-purchase belief

Prior belief has been extensively studied from many perspectives such as marketing (Olson and Dover, 1979), psychology (Katona, 1972), organisational behavior (Jones and Vroom, 1964), and others. Consumer pre-purchase belief or consumer expectation is a pre-trial belief about uncertain outcomes of a product. For the new product launch, consumer pre-purchase beliefs are formed in the pre-launch marketing process (Eliashberg and Robertson, 1988). Ulaga and Chacour (2001) show that consumers' value beliefs are based on product features such as quality, price, appearance, and brand. Besides product features, Eliashberg and Robertson (1988) point out that consumer pre-purchase beliefs are heavily affected by marketing activities. Beard and Easingwood (1996) list several detailed marketing actions of a new product launch, such as technological superiority, product support, and advertising.

Recently, several scholars have noticed that pre-purchase beliefs may affect consumers' purchasing decisions by moderating the effects of loss aversion (Karle and Peitz, 2014; Minnema et al., 2016) because prior beliefs about future outcomes determine the reference points (Kőszegi and Rabin, 2006; Fuster and Ericson, 2010). However, consumer psychological loss does not always exist especially when retailers offer full refunds or free trials.

In summary, most extant studies focus on the potential factors affecting pre-purchase beliefs and the interaction between pre-purchase beliefs and purchasing decisions. However, to the best of our knowledge, there is a lack of research examining how retailers respond from an Operations Management (OM) perspective. Moreover, pre-purchase beliefs generate a critical gap between the pre-purchase beliefs and posterior product valuation which can affect consumer satisfaction and sales. However, this gap and its relationship to purchasing decision-making have not been explicitly analyzed.

2.3 Newsvendor problem with consumer behavior

The well-known newsvendor problem attracted much attention since the 1950s (Whitin, 1955). Nowadays, the newsvendor model not only comprehensively captures the intricate decision-making process of retailers in traditional product sales but also has emerged as a widely employed framework in the context of new product retailing (e.g., Wu et al., 2021; Prasad et al., 2011; Zhao & Stecke, 2010; Choi, 2018). However, most studies assume that market demand is exogenously given and do not consider consumer buying decisions. Recently, Aviv and Pazgal (2008) show that retailers may lose a potential revenue of about 20% if they incorrectly assume that strategic consumers are myopic. Therefore, many researchers are interested in how to incorporate consumer behaviors and consider consumer buying decisions in traditional operations models. These consumer buying behaviors include strategic waiting behavior (Anderson and Wilson, 2003; Wei and Zhang, 2018b; Mishra and Venkataraman, 2022; Wu et al., 2021), loss aversion with reference dependence (Baron et al., 2015), panic buying (Zheng et al., 2021), social comparison (Bearden and Rose, 1990), inertia buying (Zhao et al., 2012), impulse buying (Liu et al., 2013) and opportunistic buying (Ali Ülkü and Gürler, 2018), among others.

Among all consumer behaviors, strategic waiting behavior is the one of most extensively studied. Coase (1972) introduces consumer strategic waiting behavior and argues that this behavior negatively affects a monopolist's profit. To reduce or eliminate the negative impacts of strategic waiting, some research proposes several ways to respond to strategic consumers, such as fixed pricing (Su and Zhang, 2008), price-commitment (Aviv and Pazgal, 2008), price-matching (Lai et al., 2010; Zhao et al., 2019), and so on. We refer interested readers to Wei and Zhang (2018a) for a detailed review of strategic consumer behavior and operational strategies.

In summary, the newsvendor problem with consumer behavior has attracted scholarly attention in recent years. Different from other perspectives, OM scholars focus on how retailers respond to consumer behaviors. To the best of our knowledge, no prior studies have studied consumers' pre-purchase beliefs and incorporated buying behaviors driven by pre-purchase beliefs into a retailer's decision-making process.

2.4 Literature positioning

The existing body of literature on new product diffusion has underscored the importance of comprehending consumer behavior during the new product launch process and the evolving role of consumers in the marketplace (e.g., Lacava & Tull, 1982; Eliashberg & Robertson, 1988; Beard & Easingwood, 1996; Zhao & Stecke, 2010; Liang et al., 2014; Burmester et al., 2015; Yu et al., 2016; Lobel et al., 2016; Choi, 2018; Feldman et al., 2019; Chen & Jiang, 2021; Disch, 2023). Furthermore, research on consumer beliefs has shed light on the notion that pre-purchase beliefs take shape during the new product launch phase and wield significant influence over consumers' purchasing decisions (e.g., Olson & Dover, 1979; Spreng et al., 1996; Mellers et al., 1999; Bhattacherjee, 2001; Kőszegi & Rabin, 2006; Karle & Peitz, 2014. However, a notable gap in the literature pertains to the exploration of how pre-purchase beliefs impact retailers' operational decisions and their choices regarding selling strategies, particularly in the context of new products. Thus, our study endeavors to bridge this research void by investigating the ramifications of consumers' pre-purchase value beliefs on retailers' operational decisions and the selection of selling strategies in the context of new product launches.

Table 1 Model notation

p	Selling price per unit
c	Purchasing cost per unit, $c < p$
Q	Order quantity
D	Market demand
N	Market size, with mean μ_N, standard deviation σ_N, CDF $F_N(\cdot)$ and PDF $f_N(\cdot)$
v_0	Consumer pre-purchase belief in the value of the new product
v	Product realized valuation which has a cumulative distribution function (CDF) $F_v(y)$ and a probability distribution function (PDF) $f_v(y)$ with a support $[c, \bar{v}]$
r_b	Reservation utility when selling price exceeds consumer's pre-purchase belief, $r_b \geq 0$

Regarding research methods, while previous studies have empirically identified potential factors that influence pre-purchase beliefs and their interaction with purchasing decisions (e.g., Olson & Dover, 1979; Spreng et al., 1996; Mellers et al., 1999; Burmester et al., 2015), there has been limited attention given to explicitly modeling the purchasing decision process and considering the gap between prior beliefs and subsequent valuation. Additionally, although the newsvendor model is a widely used tool for capturing retailers' decision-making processes and has been applied in new product retailing scenarios (e.g., Wu et al., 2021; Zhao & Stecke, 2010; Choi, 2018), the literature on the newsvendor problem with consumer behavior has largely overlooked the aspect of consumer purchasing driven by pre-purchase beliefs. Therefore, our study makes a substantial contribution by incorporating the explicit modeling of purchasing decisions influenced by pre-purchase beliefs and analyzing how retailers should adapt to consumer beliefs to optimize their operational decisions and selling strategies. Ultimately, our research offers valuable insights to retailers and marketers seeking effective strategies for launching new products in highly competitive markets, and these insights are consolidated and summarized in the concluding section.

3 Problem settings

Our general setting is that a retailer launches and sells a new product over a selling period. Table 1 summarises the notation used in the paper.

3.1 Retailer setting

When selling a new product, the retailer announces the selling price p and orders a quantity Q at a unit cost of c. All leftover units have zero salvage value. The market size N is random and follows the distribution $F_N(\cdot)$. We define the generalized failure rate of the market size as $G(x) = \frac{x f_N(x)}{\bar{F}_N(x)}$, and further assume that the market size has an increasing generalized failure rate (IGFR); that is, $G'(x) \geq 0$, which is satisfied by many common distributions such as normal, uniform, and gamma.

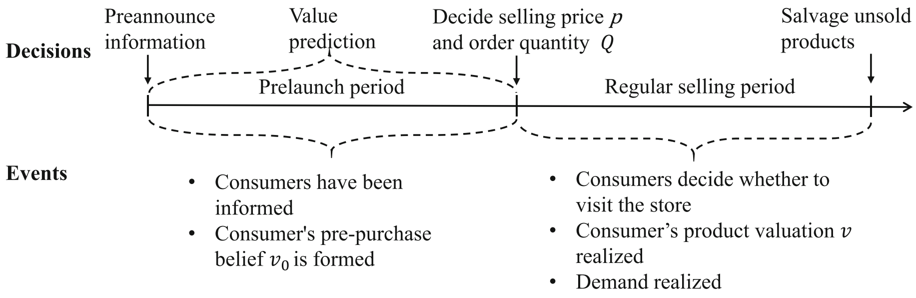


Fig. 1 Timeline of decisions and events

The selling season is divided into two periods: a prelaunch period and a regular selling period. At the beginning of the prelaunch period, the retailer preannounces the product features and information to consumers. Informed pre-belief consumers can anticipate the value of the product and form their own pre-purchase beliefs on the value. In the meantime, the retailer predicts the distribution of consumer product valuation and estimates consumers' pre-purchase beliefs. Then, at the beginning of the regular period, the retailer simultaneously sets the selling price and places the order. Figure 1 summarises and illustrates the retailer's decisions.

3.2 Consumer settings

3.2.1 Consumer pre-purchase belief and product valuation

Consumer's pre-purchase belief refers to the customer's prior valuation (expected value) of a product, whereas product valuation is the realized (posterior) valuation after the product has been fully experienced. Consumers form pre-purchase beliefs during the prelaunch period (see Fig. 1), where consumers' pre-purchase beliefs can be affected by many factors, including technological features, quality, marketing promotion, and product support. Since consumers' pre-purchase beliefs v_0 is formed before the selling price is announced, we assume that v_0 defined on $[c, \bar{v}]$ is exogenously given, where $\bar{v}$ is an upper bound of the product valuation. Note that since consumers have not experienced the product during the prelaunch period, the value of consumer's pre-purchase belief is mainly based on the information provided by the firm.

In practice, the consumer purchase intention scale survey is an effective and widely used tool to estimate consumers' pre-purchase beliefs for a new product. Besides the survey, there also exist other approaches like cheap talk (Brummett et al., 2007), bayesian analysis (Lacava and Tull, 1982), and meta-analysis (Schmidt and Bijmolt, 2020). We refer interested readers to Breidert et al. (2006) who provide a systematic overview. Further, we assume that consumers' product valuations are uncertain for retailers, but the distribution of consumer valuation can be predicted ex-ante (before the regular selling period).[2] More specifically, in line with prior research by Aviv and Pazgal (2008) and Osadchiy and Bendoly (2015), we assume that product valuation v is a random variable defined on $[c, \bar{v}]$ and with a CDF of

[2] We remark that this assumption has been justified and widely applied by extant literature, e.g., "customers know their individual valuations, but the retailer (monopolist) is only privy to the statistical distribution characteristics" (Aviv et al., 2009) and "the seller is unable to observe each customer's realized valuations, but may know the overall distribution of consumers based on historical sales data" (Fay and Xie, 2010).

$F_v(\cdot)$ and a PDF of $f_v(\cdot)$. To keep the problem tractable, we assume that all consumers have the same valuation distribution. Then, based on the consumers' pre-purchase beliefs and the estimation of consumers' product valuation, the retailer decides the selling price and order quantity simultaneously.

3.2.2 Consumer surplus and classification

Since different consumers have different responses when facing a gap between their pre-purchase beliefs and the announced price, we introduce consumer heterogeneity by grouping consumers with pre-purchase beliefs into two types: "pre-belief consumers" (B), whose purchasing decisions are solely driven by pre-purchase beliefs, and "pre-belief-and-surplus-driven consumers" (BS), whose purchasing decisions are driven by both pre-purchase beliefs and consumer surplus. B and BS consumers form their pre-purchase beliefs in the value of the product during the prelaunch period. During the regular selling period, they decide whether or not to visit the store to evaluate the product before making a purchase decision. The difference between the two types of consumers is how to respond when the announced price is higher than their pre-purchase beliefs. Let α_B and α_{BS} denote the market share of B and BS consumers respectively, where $\alpha_B, \alpha_{BS} \in [0, 1]$. Therefore, the market sizes of B and BS consumers are $N_B = \alpha_B N$ and $N_{BS} = \alpha_{BS} N$, where $\alpha_B + \alpha_{BS} = 1$. In Sect. 6.2, we consider the extension that also includes regular surplus-driven consumers.

For B consumers, if the product is "overpriced", i.e., the announced selling price is higher than the pre-purchase belief, then they never visit the store. Therefore, there is no purchasing at all even if the surplus is nonnegative.[3] In other words, B consumers evaluate the product at the store and then buy the product if the product's realized valuation meets or exceeds consumers' pre-purchase beliefs. Figure 2a summarizes the decisions of B consumers. For B consumers, consumer surplus and its expectation are defined as

$$u_B(p) = \begin{cases} v - p, & \text{if } v \geq v_0 \text{ and } p \leq v_0; \\ 0, & \text{otherwise,} \end{cases}$$

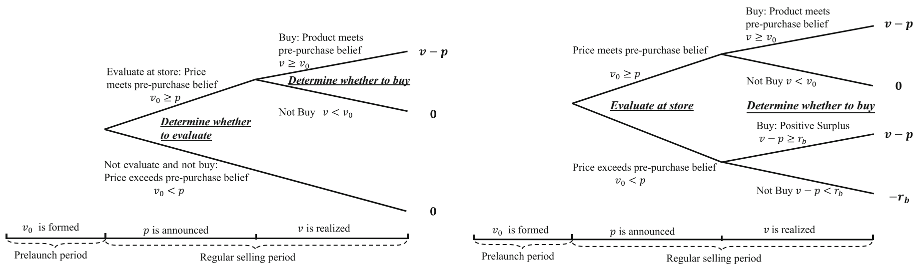
and

$$U_B(p) := E(u_B(p)) = \int_{v_0}^{\bar{v}} (x - p)^+ dF_v(x). \tag{1}$$

B consumers make purchases if $U_B(p) \geq 0$. Recall that regular surplus-driven consumers (for short, S consumers) make a purchasing decision based on whether the net utility between the value of a product and the price a consumer pays is nonnegative. If B consumers buy a product that does not meet their pre-purchase beliefs but has a nonnegative surplus, i.e., $v < v_0$ and $v - p \geq 0$, then B consumers are indifferent to regular surplus-driven consumers (which will be discussed in Sect. 6.2) because consumer pre-purchase belief plays no role in determining whether or not to buy.[4] Therefore, we restrict pre-belief consumers to those who only purchase products that align with their pre-purchase beliefs.

[3] Pre-belief consumers may have another decision-making process, i.e., comparing the valuation v and the pre-purchase belief v_0 first, then making a purchase if the surplus $v - p$ is nonnegative. We remark that the two different decision-making processes have the same expected utility $U_B(p)$, thereby the difference in the decision-making process does not affect our modeling and results.

[4] Considering a free product as a special case, i.e., $p = 0$, if pre-belief consumers consider buying regardless of whether pre-purchase beliefs are met, then they behave the same as surplus-driven consumers.



(a) Pre-belief Consumer (b) Pre-belief-and-surplus-driven Consumer

Fig. 2 Decision tree for consumers with pre-purchase beliefs

Different from B consumers, BS consumers still consider evaluating and buying the product even if the product is "overpriced". In other words, besides consumer pre-purchase beliefs, nonnegative consumer surplus can also drive the purchase decisions of BS consumers. Figure 2b summarizes the decisions of BS consumers. If the announced price is lower than the consumer's pre-purchase belief, then B and BS consumers make purchasing decisions in the same way. However, choosing to evaluate an "overpriced" product at a store is costly and can lead to disutility if the product is finally confirmed to be unwanted. Therefore, BS consumers need an additional surplus (reservation utility) to cover such potential disutility from evaluating an "overpriced" product, i.e., there is a threshold (minimum level) of consumer surplus r_b that must be obtained to make a purchase. The reservation utility r_b is usually related to the purchasing costs. For example, to plan a shopping trip to identify potentially unwanted products ($p > v_0$), consumers often invest time and energy into the trip and thereby face a purchasing cost r_b to figure out the real value of the product and decide whether or not to buy. We remark that the purchasing cost r_b as an ex-post cost is incurred when a consumer does not get/purchase the product in the end. Extant literature has noticed that consumers incur ex-post purchasing costs and impose these costs through buying decisions. For example, Ho et al. (1998) consider that a planned shopping trip is associated with an additional ex-post travel-related purchasing cost. Su and Zhang (2009) show that consumers incur ex-post costs when the desired product is out of stock, however, such cost never appears when the product is available. Further, the ex-post cost can also be specified as frictional cost (Hann and Terwiesch, 2003), search/visit cost (Cachon and Feldman, 2015), hassle cost (Hviid and Shaffer, 1999), and discovery cost (Desai et al., 2010).

For BS consumers, consumer surplus is defined as: if $v_0 < p$, then

$$u_{BS}(p) = \begin{cases} v - p, & \text{if } v - p \geq r_b, \\ -r_b, & \text{otherwise;} \end{cases}$$

if $v_0 \geq p$, then $u_{BS}(p) = u_B(p)$. Its expectation is: if $v_0 \leq p$, then

$$U_{BS}(p) := E(u_{BS}(p)) = \int_{p+r_b}^{\bar{v}} (x - p) dF_v(x) + \int_{c}^{p+r_b} (-r_b) dF_v(x); \tag{2}$$

otherwise, $U_{BS}(p) = U_B(p)$. BS consumers make purchases if the expected surplus $U_{BS}(p) \geq 0$.

4 Optimal pricing and ordering decision

Since consumers with pre-purchase beliefs have two different types, in this section, we determine the optimal order quantity and selling price for each type of consumer.

4.1 Selling to pre-belief consumers

In a market consisting of only pre-belief consumers, i.e., $N_B = N$, the fraction of all consumers whose beliefs are met is $E(I(v_i \geq v_0)) = \bar{F}_v(v_0)$, where $I(k)$ is an indicator function, i.e., $I(k) = 1$ if k is true, and otherwise $I(k) = 0$. For consumers whose pre-purchase beliefs are met or exceeded, the selling price should be set so that these consumers can make immediate purchases when they visit the store. As discussed in Sect. 3.2.2, this implies that $U_B(p) \geq 0$ must hold. From (1), we have

$$\int_{v_0}^{\bar{v}} (x - p) dF_v(x) \geq 0 \quad \text{and} \quad v_0 \geq p,$$

which imply

$$p \leq \min \left\{ \frac{\int_{v_0}^{\bar{v}} x dF_v(x)}{\bar{F}_v(v_0)}, v_0 \right\} = v_0.$$

For a price below the pre-purchase belief, all consumers whose pre-purchase beliefs are met choose to buy. Therefore, for a given N_B where $N_B = N$, the pre-belief demand is

$$D(v_0) = \sum_{i=1}^{N} E(I(v_i \geq v_0)) = N\bar{F}_v(v_0). \tag{3}$$

The retailer's profit is

$$\pi(Q, p) = p \min\{Q, N\bar{F}_v(v_0)\} - cQ,$$

and its expectation is

$$\Pi(Q, p) := E(\pi(Q, p)) = (p - c)Q - p\bar{F}_v(v_0) \int_0^{\frac{Q}{\bar{F}_v(v_0)}} F_N(x)dx.$$

Since the highest price that consumers are willing to pay is v_0, i.e., the desired value for the product, the retailer's optimal selling price must satisfy $p^* \leq v_0$. Since the market demand $D(v_0)$ is independent of the selling price and the expected profit is increasing in p, the retailer would price the product at v_0 and extract all consumer surplus, i.e., $p^* = v_0$. Under this formulation, pricing and ordering decisions are separable.[5] Note that such formulation is based on the rational expectations equilibrium which has been widely used in operations models, e.g., Stokey (1981), Su (2009), Cachon and Swinney (2009), Su and Zhang (2008), Su and Zhang (2009). Thus, we have the following result.

[5] We remark that if demand is price-dependent, then the expected profit may not be increasing in p which implies that pricing at v_0 may not be able to maximize the retailer's profit. On the contrary, achieving profit maximization may cause consumer churn. Therefore, the retailer should tradeoff profit maximization and inducing all consumers to buy when they are in conflict.

Proposition 4.1 *When selling to pre-belief consumers only, the optimal order quantity and selling price are*

$$Q^* = \bar{F}_v(v_0)F_N^{-1}\left(\frac{v_0 - c}{v_0}\right) \quad and \quad p^* = v_0.$$

The corresponding expected profit is

$$\Pi(Q^*, p^*) = v_0\bar{F}_v(v_0)\int_0^{F_N^{-1}(\frac{v_0-c}{v_0})} xdF_N(x).$$

Note that $D(v_0)$ defined in (3) is belief-dependent. As pre-purchase beliefs increase, consumers' pre-purchase beliefs are less likely to be met, which results in a demand reduction. Therefore, to measure the change in demand in response to a change in pre-purchase beliefs, we introduce the concept of belief elasticity of demand. Our definition of belief elasticity is similar to the definition of price elasticity. More specifically, let e denote the belief elasticity of mean demand $\mu_D(v_0)$; then, $e = -\frac{v_0\mu_D'(v_0)}{\mu_D(v_0)}$, where $\mu_D(v_0) = E(D(v_0)) = \mu_N\bar{F}_v(v_0)$. We define that the mean demand has an increasing belief elasticity (IBE) if $\frac{de}{dv_0} \geq 0$. The IBE property means that increased pre-purchase beliefs cause substantial reductions in demand. We remark that the demand has an IBE if the consumer valuation satisfies some common distributions such as uniform and exponential.

4.2 Selling to pre-belief-and-surplus-driven consumers

Next, we consider a market consisting of only pre-belief-and-surplus-driven consumers, i.e., $N_{BS} = N$. We follow the assumption that all consumers are identical. For heterogeneity of consumer's pre-purchase belief, we will discuss in Sect. 6.1.

As discussed in Sect. 3.2.2, two types of consumers behave the same if the announced selling price meets the consumer's pre-purchase belief. Therefore, in the case of $p \leq v_0$, the optimal decisions are given by Proposition 4.1. To avoid a trivial problem, in this section, we focus on the scenario that the product is "overpriced", i.e., $p > v_0$. In this scenario, two types of consumers are different, i.e., B consumers never buy whereas BS consumers will make purchases if consumer surplus is higher than a threshold. The fraction of BS consumers who choose to buy is $E(I(v_i - p \geq r_b)) = \bar{F}_v(p + r_b)$. To ensure that BS consumers will buy, $U_{BS}(p) \geq 0$ must hold. From equation (2), we have

$$U_{BS}(p) = \mu_v - p - 2r_bF_v(p + r_b) + \int_c^{p+r_b} F_v(x)dx.$$

Clearly, $U_{BS}(p)$ is decreasing in p. As a result, there exists a critical p_0 where $p_0 > v_0$ such that consumers have zero surplus, i.e., $U_{BS}(p_0) = 0$, or

$$\mu_v - p_0 - 2r_bF_v(p_0 + r_b) + \int_c^{p_0+r_b} F_v(x)dx = 0. \tag{4}$$

The demand of BS consumers is $D(r_b) = \sum_{i=1}^{N} E(I(v_i - p \geq r_b)) = N\bar{F}_v(p + r_b)$. The retailer's profit is $\pi(Q, p) = p\min\{Q, N\bar{F}_v(p + r_b)\} - cQ$, and its expectation is

$$\Pi(Q, p) := E(\pi(Q, p)) = (p - c)Q - p\bar{F}_v(p + r_b)\int_0^{\frac{Q}{\bar{F}_v(p+r_b)}} F_N(x)dx.$$

The corresponding optimal decisions are formalized as follows.

Proposition 4.2 *When selling to pre-belief-and-surplus-driven consumers only, the optimal order quantity and selling price are*

$$p^* = \begin{cases} p_0, & \text{if } p_0 > v_0; \\ v_0, & \text{if } p_0 \le v_0; \end{cases} \quad \text{and} \quad Q^* = \begin{cases} Q^*(p_0) = \bar{F}_v(p_0 + r_b) F_N^{-1}(\frac{p_0 - c}{p_0}), & \text{if } p_0 > v_0; \\ Q^*(v_0) = \bar{F}_v(v_0) F_N^{-1}(\frac{v_0 - c}{v_0}), & \text{if } p_0 \le v_0; \end{cases}$$

where p_0 *satisfies* $\mu_v - p_0 - 2r_b F_v(p_0 + r_b) + \int_c^{p_0 + r_b} F_v(x)dx = 0$. *The corresponding expected profit is*

$$\Pi(Q^*, p^*) = \begin{cases} p_0 \bar{F}_v(p_0 + r_b) \int_0^{F_N^{-1}(\frac{p_0 - c}{p_0})} x dF_N(x), & \text{if } p_0 > v_0; \\ v_0 \bar{F}_v(v_0) \int_0^{F_N^{-1}(\frac{v_0 - c}{v_0})} x dF_N(x), & \text{if } p_0 \le v_0. \end{cases}$$

Note that p_0 *is decreasing with respect to the reservation utility* r_b, *i.e.*, $dp_0/dr_b \le 0$, *and there exists a critical reservation utility* $\hat{r}_b$ *such that* $p_0(\hat{r}_b) = v_0$. *If* $r_b \ge \hat{r}_b$, *then the optimal price for selling to BS consumers is identical to that of selling to B consumers,* $p^* = v_0$; *otherwise,* $p^* = p_0$.

Proposition 4.2 shows that considering to buy overpriced products increases the selling price, but decreases the fraction of BS consumers who choose to buy. Therefore, whether the retailer can make more profit from selling to BS consumers depends on the tradeoff between the profit from an increased margin and loss from a reduced sale. Further, it also shows that the product can be sold at a high price if BS consumers have a relatively low reservation utility. Note that when $r_b = 0$, the corresponding p_0 is the selling price for selling to all surplus-driven consumers that we will discuss in Sect. 6.2. On the other hand, a higher reservation utility prevents BS consumers from evaluating products at stores, i.e., BS and B consumers behave in the same way. Therefore, for a high reservation utility, i.e., $r_b \ge \hat{r}_b$, the selling price and ordering decision for BS consumers are identical to those for selling to B consumers.

It should also be noted that the optimal price and order quantity have different continuities on reservation utility. Specifically, the optimal price is continuous at the critical reservation utility $\hat{r}_b$, i.e., $\lim_{r_b \to \hat{r}_b} p_0 = v_0$, but the optimal order quantity is not, i.e., $\lim_{r_b \to \hat{r}_b} Q^*(p_0) < Q^*(v_0)$. We denote this ordering gap at $\hat{r}_b$ by $\Delta_{Q^*} = \lim_{r_b \to \hat{r}_b} Q^*(v_0) - Q^*(p_0) = (\bar{F}_v(v_0) - \bar{F}_v(v_0 + \hat{r}_b)) F_N^{-1}(\frac{v_0 - c}{v_0}) > 0$. It is clear that the ordering gap is not related to the uncertainty of market size $F_N(\cdot)$, but is caused by the change in the proportion (likelihood) BS consumers choose to buy, i.e., $\bar{F}_v(v_0) - \bar{F}_v(v_0 + \hat{r}_b)$ or $\text{Prob}\{v - v_0 \ge 0\} - \text{Prob}\{v - p_0(\hat{r}_b) \ge \hat{r}_b\}$. When selling the product at the critical selling price $p^* = v_0 = p_0(\hat{r}_b)$, B consumers make purchases immediately if consumer pre-purchase belief is met, i.e., $v \ge v_0 = p_0(\hat{r}_b)$. However, immediately buying for BS consumers may lead to a negative utility because consumer surplus may be less than reservation utility.

The observed discontinuity in consumer behavior offers valuable managerial insights. Firstly, retailers should take into account the negative impact of reservation utility on BS consumers, as it reduces the likelihood of making a purchase. To address this issue, retailers can implement effective strategies such as leveraging fashion trends and weather-related correlations to increase consumer visits to the store, as well as reducing travel-related costs for consumers (Yu et al., 2021).

Secondly, it's worth noting that reservation utility does not influence the purchase decisions of BS consumers as long as their pre-purchase beliefs are met, meaning that they perceive the value (v_0) to be higher than the zero-surplus selling price (p_0). Therefore, managing and adjusting pre-purchase beliefs is a powerful tool that retailers can use to eliminate the negative effects of reservation utility completely. By communicating the value of a product effectively, retailers can influence consumer pre-purchase beliefs and increase the likelihood of a purchase.

5 Optimal selling strategy

In this section, we study the optimal selling strategy of the retailer in the face of a market consisting of both B and BS consumers, i.e., $N_B = \alpha_B N$ and $N_{BS} = \alpha_{BS} N$ where $\alpha_B = 1 - \alpha_{BS}$. Based on our analysis in Sect. 4, "overpricing" (i.e., $p > v_0$) will prevent B consumers. "Underpricing" (i.e., $p \le v_0$) will attract both types of consumers, but may result in profit loss due to offering too much discounts to BS consumers. Therefore, the retailer has two selling strategies: selling to all versus selling to BS only.

By Proposition 4.2, the optimal decisions and the correspondingly maximal expected profit of selling to BS only strategy are $p^* = p_0$, $Q^* = \alpha_{BS}\bar{F}_v(p_0 + r_b)F_N^{-1}(\frac{p_0 - c}{p_0})$ and $\Pi_{BS}(p^*, Q^*) = \alpha_{BS} K(p_0, r_b)$. For selling to all (B and BS) strategy, the product is "under-pricing" which indicates that B and BS consumers behave the same. Therefore, by Proposition 4.1, the optimal decisions and the correspondingly maximal expected profit are $p^* = v_0$, $Q^* = \bar{F}_v(v_0)F_N^{-1}(\frac{v_0 - c}{v_0})$ and $\Pi_A(p^*, Q^*) = K(v_0, 0)$. In the following, we compare the optimal profits of both strategies as follow.

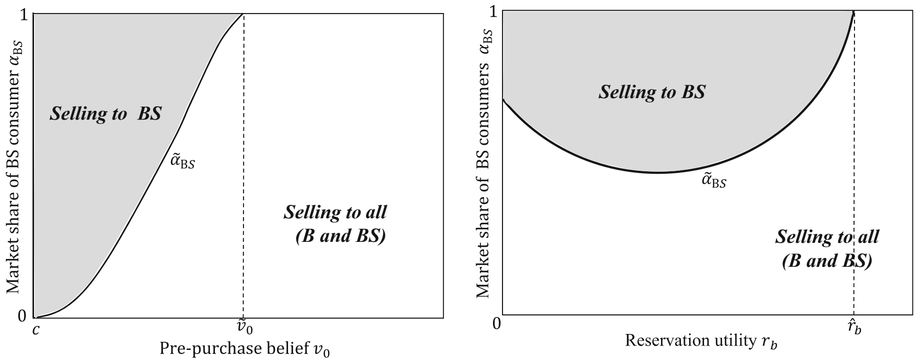
Proposition 5.1 (Selling to All vs. Selling to BS only)

- *If consumer pre-purchase belief is lower than a threshold and the market size of BS consumers is higher than a threshold, i.e., $v_0 \le \tilde{v}_0$ and $\alpha_{BS} \ge \tilde{\alpha}_{BS}$, then selling to BS consumers only is more profitable.*
- *Otherwise, selling to all consumers with pre-purchase beliefs is more profitable.*

The critical market share is $\tilde{\alpha}_{BS} = \frac{K(v_0,0)}{K(p_0,r_b)}$ and the critical consumer pre-purchase belief $\tilde{v}_0$ satisfies $K(\tilde{v}_0, 0) = K(p_0, r_b)$, where $K(x_1, x_2) = x_1 \bar{F}_v(x_1 + x_2) \int_0^{F_N^{-1}(\frac{x_1 - c}{x_1})} y dF_N(y)$.

Figure 3a provides a graphical illustration for which selling strategy the retailer should implement. Intuitively, for a very high pre-purchase belief, i.e., $v_0 \ge \tilde{v}_0$, selling to all dominates because this strategy yields a larger demand and the product can be sold at a higher profit margin. However, if consumer pre-purchase belief is relatively low, i.e., $v_0 \le \tilde{v}_0$, then whether selling to all depends on the market share of B consumers. Since a lower pre-purchase belief leads to a decrease in selling price, selling to all is more profitable only if the market share of B consumers is relatively large. Otherwise, selling to BS by setting a higher price than consumer pre-purchase belief is optimal because the added profit outweighs the profit loss from reduced sales. Note that selling to all strategy sets the optimal selling price to meet consumer pre-purchase belief, i.e., $p^* = v_0$. Therefore, the retailer cannot benefit from the surplus-driven buying behavior of BS consumers because BS consumers behave in the same way as B consumers under this strategy. However, selling to BS consumers is more profitable for the retailer in the shadow area because surplus-driven buying behavior increases the selling price and the overall profit when consumer pre-purchase belief is relatively low.

Since both critical market share $\tilde{\alpha}_{BS}$ and the optimal price p_0 are dependent on r_b, the following result discusses the impacts of consumer's reservation utility on the retailer's optimal selling strategy.



(a) Consumer pre-purchase belief (b) Consumer reservation utility

Fig. 3 Optimal selling strategy: selling to all versus selling to BS only

Corollary 1 *For a given pre-purchase belief v_0, if the market size of BS consumers is higher than a threshold and the consumer's reservation utility is lower than a threshold, i.e., $\alpha_{BS} \geq \tilde{\alpha}_{BS}$ and $r_b \leq \hat{r}_b$, then selling to BS only is more profitable; otherwise, selling to all is more profitable, where critical market share $\tilde{\alpha}_{BS} = \frac{K(v_0,0)}{K(p_0,r_b)}$ and critical reservation utility $\hat{r}_b$ satisfies $K(v_0, 0) = K(p_0(\hat{r}_b), \hat{r}_b)$.*

Proof The proof is analogue to the proof of Proposition 5.1. So we omit here. □

Figure 3b graphically shows that selling to BS is more profitable only if BS consumers have a moderate (small) reservation utility and a relatively large population, i.e., $r_b \in [\max\{\underline{r}_b, 0\}, \bar{r}_b]$ and $\alpha_{BS} \leq \tilde{\alpha}_{BS}$. The reason behind Fig. 3b can be explained by the relationship between the optimal selling price and reservation utility (r_b). As reservation utility increases, the optimal selling price for selling to BS consumers decreases. This means that a large reservation utility can result in a very low or even zero profit margin, making it unprofitable for retailers to sell to these consumers. In contrast, a small reservation utility can increase the selling price, which can be higher than the consumer's pre-purchase belief. However, this also results in a smaller demand due to the higher margin. Therefore, for a very small reservation utility, the decision to sell to BS consumers depends on the tradeoff between the added profit from a higher margin and the potential loss of profit from reduced sales.

6 Heterogeneous pre-purchase beliefs and buying behaviors

To gain further insights into the impacts of diversity in consumer behaviors on the retailer's optimal selling strategy, we expand our research by considering two aspects of consumer heterogeneity: their pre-purchase beliefs and their buying behaviors.

6.1 Heterogeneous pre-purchase beliefs

Since consumer pre-purchase beliefs differ, we divide consumers into two segments: high-belief (H) and low-belief (L). The pre-purchase beliefs of H and L consumers are denoted by v_0^H and v_0^L respectively, where $v_0^L = v_0$, $v_0^H = v_0 + \Delta_{v_0}$ and $\Delta_{v_0} = v_0^H - v_0^L \geq 0$ represents the difference in consumers' pre-purchase beliefs between two types of consumers. Further, we let α_H be the market share of H consumers in the total market. Therefore, low-belief consumers have a market share $\alpha_L = 1 - \alpha_H$. Since consumers can be either BS or B, and their pre-purchase beliefs can be either high or low, consumers in the market have four different types: HB, LB, HBS, and LBS. Correspondingly, the proportions of each type of consumers are $\alpha_H\alpha_B, \alpha_L\alpha_B, \alpha_H\alpha_{BS}$ and $\alpha_L\alpha_{BS}$, where $\sum_{i\in\{H,L\}}\sum_{j\in\{B,BS\}}\alpha_i\alpha_j = 1$.

Since consumer pre-purchase beliefs do not affect the optimal selling price of BS consumers if consumers have a relatively big reservation utility, i.e., $p^* = p_0(\geq v_0)$ is independent of v_0, we discuss the optimal selling strategy in the following three scenarios: $p_0 \leq v_0^L \leq v_0^H$, $v_0^L \leq p_0 \leq v_0^H$ and $p_0 \geq v_0^H \geq v_0^L$, which corresponds to $r_b \geq r_b(v_0^L) \geq r_b(v_0^H)$, $r_b(v_0^L) \geq r_b \geq r_b(v_0^H)$ and $r_b(v_0^L) \geq r_b(v_0^H) \geq r_b$ where critical values $r_b(v_0^L)$ and $r_b(v_0^H)$ are the solutions of $U_{BS}(v_0^L, r_b(v_0^L)) = U_{BS}(v_0^H, r_b(v_0^H)) = 0$ [see Eq. (4)]. More specifically, when $p_0 \leq v_0^L \leq v_0^H$, offering p_0 for BS consumers is never optimal. Therefore, all BS consumers behave in the same way as B consumers. In other words, there are only two types of consumers (H and L) in the market. Selling to H by using a high-pricing strategy will prevent consumers with a low belief from buying. However, selling to all at a low price will attract all types of consumers, but may result in lost profits due to offering a discount for high-belief consumers. As a result, the retailer has two selling strategies: selling to H and selling to all.

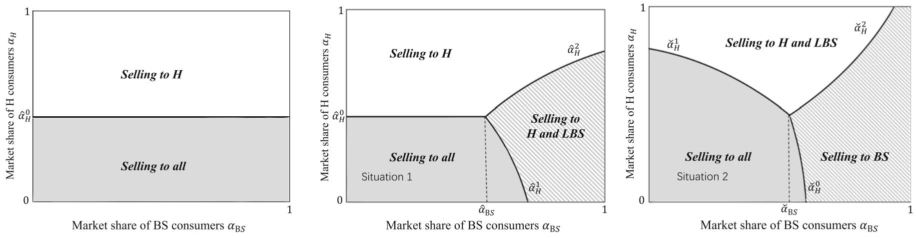
When $v_0^L \leq p_0 \leq v_0^H$, the retailer will never offer a price that is higher than v_0^H, i.e., HBS consumers behave in the same way as HB consumers. Therefore, there are three types of consumers (H, LB, and LBS) in the market. Note that offering v_0^H (p_0) will prevent all L (LB) consumers from buying. However, selling at v_0^L will attract all types of consumers. As a result, the retailer has three selling strategies: selling to H, selling to H and LBS, and selling to all.

When $p_0 \geq v_0^H \geq v_0^L$, four types of consumers (HB, LB, HBS, and LBS) behave differently. Note that offering p_0 (v_0^H) will prevent all B (LB) consumers from buying. However, selling at v_0^L will attract all types of consumers. As a result, the retailer has three selling strategies: selling to BS, selling to H and LBS, and selling to all.

Note that, based on Proposition 5.1, the maximal profits of all selling strategies are: selling to all, $\Pi_A = \alpha_H K(v_0^L, \Delta_{v_0}) + \alpha_L K(v_0^L, 0)$ where $p^* = v_0^L$; selling to BS, $\Pi_{BS} = \alpha_{BS}K(p_0, r_b)$ where $p^* = p_0$; selling to H, $\Pi_H = \alpha_H K(v_0^H, 0)$ where $p^* = v_0^H$; selling to H and LBS, $\Pi_{H+LBS} = \alpha_{BS}\alpha_L K(p_0, r_b) + \alpha_H K(p_0, v_0^H - p_0)$, where $p^* = p_0$ if $v_0^L \leq p_0 \leq v_0^H$, and $\Pi_{H+LBS} = \alpha_{BS}\alpha_L K(v_0^H, r_b) + \alpha_H K(v_0^H, 0)$ where $p^* = v_0^H$ if $p_0 \geq v_0^H \geq v_0^L$. After comparing the profits of all selling strategies in each scenario, the following result provides the optimal selling strategies.

Proposition 6.1 *For a given market share of BS consumers α_{BS}, there exist critical market shares of H consumers which are defined by:* $\hat{\alpha}_H^0 = \frac{K(v_0^L,0)}{K(v_0^H,0)+K(v_0^L,0)-K(v_0^L,\Delta_{v_0})}$, $\hat{\alpha}_H^1 = \frac{K(v_0^L,0)-\alpha_{BS}K(p_0,r_b)}{K(p_0,v_0^H-p_0)+K(v_0^L,0)-K(v_0^L,\Delta_{v_0})-\alpha_{BS}K(p_0,r_b)}$, $\hat{\alpha}_H^2 = \frac{\alpha_{BS}K(p_0,r_b)}{K(v_0^H,0)+\alpha_{BS}K(p_0,r_b)-K(p_0,v_0^H-p_0)}$, $\check{\alpha}_H^0 = \frac{K(v_0^L,0)-\alpha_{BS}K(p_0,r_b)}{K(v_0^L,0)-K(v_0^L,\Delta_{v_0})}$, $\check{\alpha}_H^1 = \frac{K(v_0^L,0)-\alpha_{BS}K(v_0^H,r_b)}{K(v_0^H,0)+K(v_0^L,0)-\alpha_{BS}K(v_0^H,r_b)-K(v_0^L,\Delta_{v_0})}$, $\check{\alpha}_H^2 = \frac{\alpha_{BS}(K(p_0,r_b)-K(v_0^H,r_b))}{K(v_0^H,0)-\alpha_{BS}K(v_0^H,r_b)}$. *There also exist critical market shares of BS consumers $\hat{\alpha}_{BS}$ and $\check{\alpha}_{BS}$ such that $\hat{\alpha}_H^0 = \hat{\alpha}_H^1(\hat{\alpha}_{BS}) = \hat{\alpha}_H^2(\hat{\alpha}_{BS})$ and $\check{\alpha}_H^0(\check{\alpha}_{BS}) = \check{\alpha}_H^1(\check{\alpha}_{BS}) = \check{\alpha}_H^2(\check{\alpha}_{BS})$.*

(a) *($p_0 \leq v_0^L \leq v_0^H$: Selling to H vs. Selling to All) If the market share of H consumers is relatively small, i.e., $\alpha_H \leq \hat{\alpha}_H^0$, then selling to all consumers is more profitable. Otherwise, selling to H consumers is more profitable;*



(a) $p_0 \le v_0^L \le v_0^H$ (b) $v_0^L \le p_0 \le v_0^H$ (c) $v_0^L \le v_0^H \le p_0$

Fig. 4 Optimal selling strategy under pre-purchase belief heterogeneity

(b) *($v_0^L \le p_0 \le v_0^H$: Selling to H vs. Selling to H and LBS vs. Selling to All) If $\alpha_H \le \hat{\alpha}_H^0$ & $\alpha_{BS} \le \hat{\alpha}_{BS}$ or $\alpha_H \le \hat{\alpha}_H^1$ & $\alpha_{BS} \ge \hat{\alpha}_{BS}$, then selling to all is more profitable; if $\hat{\alpha}_H^1 \le \alpha_H \le \hat{\alpha}_H^2$ & $\alpha_{BS} \ge \hat{\alpha}_{BS}$, then selling to H and LBS is more profitable; otherwise, selling to H is more profitable;*

(c) *($p_0 \ge v_0^H \ge v_0^L$: Selling to BS vs. Selling to H and LBS vs. Selling to All) If $\check{\alpha}_H^0 \le \alpha_H \le \check{\alpha}_H^2$ & $\alpha_{BS} \ge \check{\alpha}_{BS}$ holds, then selling to BS is more profitable; if $\alpha_H \ge \check{\alpha}_H^1$ & $\alpha_{BS} \le \check{\alpha}_{BS}$ or $\alpha_H \ge \check{\alpha}_H^2$ & $\alpha_{BS} \ge \check{\alpha}_{BS}$, then selling to H and LBS is more profitable; otherwise, selling to all is more profitable.*

This result shows that consumer heterogeneity in product pre-purchase belief can significantly affect the optimal pricing and selling strategies. As Fig. 4 shows, the optimal pricing strategy heavily relies on the market share of the H consumers. If more consumers have a higher belief, then selling to H consumers by pricing high is optimal; otherwise, selling to all by offering a low price is more profitable. This is because the increased profit from selling high outweighs the reduced profit from fewer purchases. This result always holds when consumer belief is relatively high or consumers have a relatively high reservation utility (see Fig. 4a), i.e., $p_0 \le v_0^L \le v_0^H$.

As consumer pre-purchase belief or reservation utility decreases, selling to LB by offering the lowest price v_0^L is never optimal. Therefore, the market share of BS consumers plays a vital role in determining the optimal selling strategy. More specifically, as Fig. 4b shows, when $v_0^L \le p_0 \le v_0^H$, selling to H and LBS is best if not only BS consumers have a relatively large market share, i.e., $\alpha_{BS} > \hat{\alpha}_{BS}$, but also H consumers have a relatively small market share, i.e., $\hat{\alpha}_H^1 \le \alpha_H \le \hat{\alpha}_H^2$. This is because the increased profit from selling to LBS at a higher price $p_0 > v_0^L$ and more purchases from H consumers outweigh the reduced profit from selling to H at a lower price and no purchases from LB consumers. As consumer pre-purchase belief or reservation utility further decreases, i.e., $v_0^L \le v_0^H \le p_0$, the retailer can charge the highest price for BS consumers. Therefore, selling to BS only is best if BS consumers have a large market share, i.e., $\alpha_{BS} > \check{\alpha}_{BS}$. This is because the increased profit from selling to H outweighs the reduced profit from no purchases of H consumers. Moreover, since selling to BS at p_0 is profitable in this scenario, selling to H and LBS dominates selling to H if H consumers have a relatively large market share, as shown in Fig. 4c.

Our findings are consistent with several real-world cases. For instance, as consumers' pre-purchase beliefs for the new generation of iPhones increase, it becomes increasingly challenging for Apple to meet these expectations under its high pricing strategy, which corresponds to selling to BS at the highest price p_0 in case (c). Recently, there was a significant mismatch between consumer pre-purchase beliefs and product performance for the iPhone XR, which resulted in a sharp drop in sales. To attract other types of consumers, Apple had

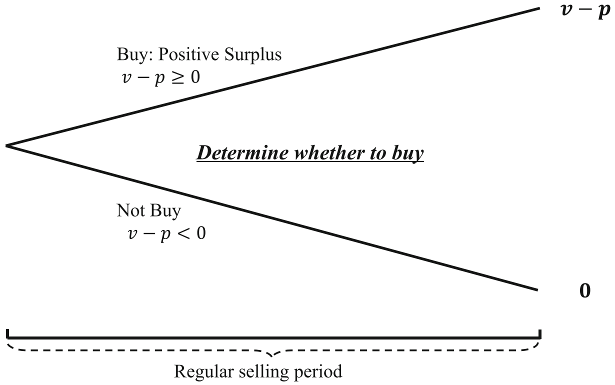


Fig. 5 Decision tree for surplus-driven consumers

Table 2 Consumer buying decisions

Consumer type	$v < p$	$p \leq v < v_0$	$v \geq v_0$
(a) $[v_0 \geq p]$			
S	Not buy	Buy	Buy
B	Not buy	Not buy	Buy
BS	Not buy	Not buy	Buy
(b) $[v_0 < p]$			
S	Not buy	Not buy	Buy
B	Not buy	Not buy	Not buy
BS	Not buy	Not buy	Buy

to cut prices, selling to H and LBS at a medium price p_0, as seen in case (b). This example illustrates the importance of understanding consumer pre-purchase beliefs and the potential impact on product performance and pricing strategies. Retailers must adjust their strategies to meet consumer needs and expectations to maintain profitability and success in the market.

6.2 Heterogeneous buying behaviors

Besides B and BS consumers, in this subsection, we consider a scenario that there also exist solely surplus-driven (S) consumers in the market. S consumers make their purchasing decisions only if the surplus $v-p$ is non-negative. Correspondingly, the expected surplus from purchasing is $U_S(p) = \int_p^{\bar{v}} (x-p)dF_v(x)$. Figure 5 shows the decision process of surplus-driven consumers and Table 2 summarizes buying decisions of all types of consumers.

For selling to S consumers, the optimal selling price p_S is to maximize the profit by letting S consumers choose to buy with zero surplus, i.e., $U_S(p_S) = 0$. Since $U_S(p)$ is decreasing in p, there exists a critical p_S such that $U_S(p_S) = 0$ or $\mu_v - p_S + \int_c^{p_S} F_v(x)dx = 0$. We remark that $p_S = p_0(0)$ because $U_{BS}(p) = U_S(p)$ when $r_b = 0$. For a market consisting of only S consumers, i.e., $N_S = N$, the surplus-driven demand is $D = \sum_{i=1}^N E(I(v_i - p \geq 0)) = N\bar{F}_v(p)$. Further, the optimal order quantity is $Q^* = F_N^{-1}(\frac{p_S - c}{p_S})\bar{F}_v(p_S)$ and the maximum expected profit is $\Pi^* := K(p_S, 0) = p_S\bar{F}_v(p_S)\int_0^{F_N^{-1}(\frac{p_S-c}{p_S})} x dF_N(x)$.

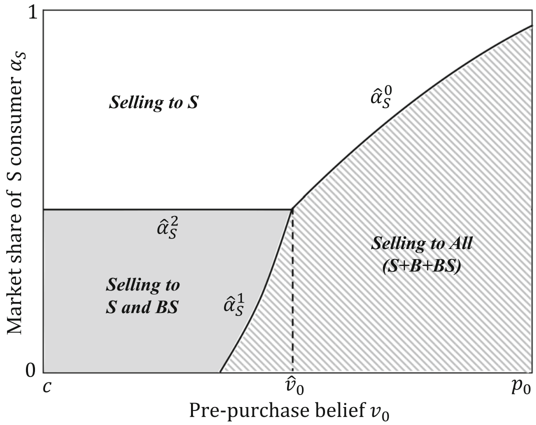


Fig. 6 Optimal selling strategy: selling to S versus selling to S and BS versus selling to all

Let $\alpha_S \in [0, 1]$ be the market share of surplus-driven consumers and β be the proportion of BS consumers. The market shares of B and BS consumer are $\alpha_B = (1-\beta)(1-\alpha_S)$ and $\alpha_{BS} = \beta(1-\alpha_S)$. Table 2 indicates that the retailer has three selling strategies: selling to all, selling to S, and selling to S & BS. Since p_0 is decreasing in r_b and $p_S = p_0(0)$, we have $v_0 < p_0 \leq p_S$. Correspondingly, the maximum profits of each selling strategy are: selling to all, $\Pi_A = K(v_0, 0)$; selling to S, $\Pi_S = \alpha_S K(p_S, 0)$; selling to B and BS, $\Pi_{B+BS} = \alpha_S K(p_0, 0) + \alpha_{BS} K(p_0, r_b)$. Based on a similar analysis as in Sect. 6.1, the following proposition provides the optimal selling strategies.

Proposition 6.2 *For a given consumer pre-purchase belief v_0, there exist a critical threshold of consumer belief $\hat{v}_0$ and three critical market shares of surplus-driven consumers $\hat{\alpha}_S^i$ ($i = 1, 2, 3$), where $\hat{v}_0$ satisfies $K(\hat{v}_0, 0) = \frac{\beta K(p_S,0)K(p_0,r_b)}{K(p_S,0)-K(p_0,0)+\beta K(p_0,r_b)}$ and critical market shares are defined as $\hat{\alpha}_S^0 = \frac{K(v_0,0)}{K(p_S,0)}$, $\hat{\alpha}_S^1 = \frac{K(v_0,0)-\beta K(p_0,r_b)}{K(p_0,0)-\beta K(p_0,r_b)}$, $\hat{\alpha}_S^2 = \frac{\beta K(p_0,r_b)}{K(p_S,0)-K(p_0,0)+\beta K(p_0,r_b)}$. If $\hat{\alpha}_S^1 \leq \alpha_S \leq \hat{\alpha}_S^2$, then selling to S consumers is the best; if $\alpha_S \leq \hat{\alpha}_S^0$ for $v_0 \geq \hat{v}_0$ or $\alpha_S \leq \hat{\alpha}_S^1$ for $v_0 \leq \hat{v}_0$, then selling to all is the best; otherwise, selling to S and BS consumers is the best.*

Figure 6 provides a graphical illustration of the case in which selling to S consumers only is profitable. It is clear that surplus-driven buying behavior and the market share of S consumers can significantly affect a retailer's selling strategy. In the comparison of the results without S consumers, as shown in Fig. 3a, it is clear the structural result remains largely unaffected by a relatively small $\alpha_S \leq \hat{\alpha}_S^2$. Moreover, we find that selling to all is still best if consumers have a relatively high pre-purchase belief. However, some changes should be noted when S consumers have a relatively high market share, i.e., $\alpha_S \geq \hat{\alpha}_S^2$. Compared with the strategy of selling to S, the strategy of selling to all or selling to S and BS has a relatively larger demand, and is more attractive when consumer pre-purchase beliefs are relatively high or S consumers have a small market share. However, if consumer pre-purchase beliefs are relatively low (or the market share of S consumers is big), then the negative effect of a reduced selling price can almost cancel out the increase in revenue. Please note that we present an additional numerical example to discuss the effect of reservation utility on the optimal strategy in Appendix A.

7 Conclusion

The practice of pre-announcing new products has gained popularity among firms, serving as a marketing strategy to generate anticipation and buzz for forthcoming releases. Nevertheless, effectively harnessing these pre-purchase beliefs to promote new products can pose a challenge for retailers, particularly when consumers have already formed pre-purchase beliefs regarding the product's value. To address this challenge, we have developed a model that captures consumer buying decisions influenced by these pre-purchase beliefs.

The existing body of literature has conducted a thorough examination of consumer behaviors in response to new products and how firms strategically adapt to these behaviors, as exemplified by a range of studies (e.g., Chen & Jiang, 2021; Feldman et al., 2019; Ji et al., 2022; Liang et al., 2014; Yu et al., 2016; Zhao & Stecke, 2010; Wu et al., 2021; Choi, 2018). Building upon this established knowledge, our study seeks to enrich the field by advancing our understanding of consumer decision-making processes within the domain of new product retail. Our research focuses on the analysis of consumers' pre-purchase beliefs regarding new products and explores how retailers can effectively market these products to consumers who have already formed such beliefs based on pre-launch announcements. Consistent with previous research, our findings confirm that consumer irrationality holds the potential to significantly impact a firm's profitability. However, our study stands out by uniquely concentrating on a specific facet of consumer behavior in the realm of new product retailing. Furthermore, our research reveals a key insight: retailers can gain distinct advantages by comprehending and capitalizing on consumers' pre-purchase beliefs. This discovery not only complements the existing body of research but also underscores the paramount importance of understanding consumer behavior in the context of new product development. While prior studies have predominantly emphasized the significance of understanding consumers' learning capabilities (e.g., Chen & Jiang, 2021; Feldman et al., 2019; Ji et al., 2022), risk preferences (e.g., Choi, Choi (2018)) and strategic buying behavior (e.g., Liang et al., 2014; Zhao & Stecke, 2010; Wu et al., 2021), our study places a particular emphasis on the pivotal role played by comprehending consumers' pre-purchase beliefs.

Our research offers three significant contributions. Firstly, we illustrate that the management and adjustment of consumer pre-purchase beliefs regarding the product's value can substantially enhance retailers' profitability. However, retailers must exercise caution in the constant elevation or reduction of consumers' expectations, as this can prove detrimental in the long term.

Secondly, we take into account the diverse responses and decisions made by consumers when their pre-purchase expectations are unmet. We distinguish between two groups: consumers driven solely by pre-purchase beliefs and those with an additional surplus-driven component in their pre-purchase beliefs. Our findings demonstrate that selling to the latter group at a higher price can be more profitable, contingent on the market size of this group and their pre-purchase beliefs.

Lastly, we take into account the diversity among consumers and unveil that the optimal selling strategy hinges on the value of consumers' pre-purchase beliefs, as well as the market sizes of those solely driven by pre-purchase beliefs and those influenced by both pre-purchase belief and surplus. Selling to consumers exclusively guided by pre-purchase beliefs becomes profitable only when their pre-purchase beliefs are relatively high and the market share of these pre-belief consumers is substantial. Neglecting consumer pre-purchase beliefs can lead to a significant loss in profits, especially when consumers' purchasing decisions are shaped by both pre-purchase belief and surplus.

Our study's results have significant managerial implications for firms in various industries, and they are consistent with real-world business scenarios. For instance, in the consumer electronics industry, firms like Apple, Huawei, and Tesla typically invest heavily in advertising campaigns to build high consumers' expectations by highlighting the unique high-performance features of their products and promoting advance selling online. By raising consumers' pre-purchase expectations, these firms cater to the increasing number of consumers with pre-purchase beliefs, which is in line with our findings.

However, value-for-money brands or products, such as Toyota and BYD, present a different scenario. These brands often downplay their new products and lower consumers' pre-purchase expectations before the product launch. They then deliver high-quality products that exceed consumers' expectations, resulting in high levels of consumer satisfaction. Toyota's introduction of Lexus in 1989 is a prime example of this approach. Before the 1990s, Toyota was not known for producing luxury vehicles, and they downplayed Lexus before its launch. This strategy worked as it let consumers more likely to be satisfied with the new product and led to increased sales.

While our research provides valuable insights into consumer behavior and pricing strategies, there are several limitations to our study. First, we assumed that the retailer has perfect knowledge of consumers' pre-purchase beliefs. However, in reality, pre-purchase beliefs may be uncertain and challenging to estimate accurately. Future research could extend our model to include uncertain value beliefs, which would provide a more realistic representation of the market. Second, our model did not account for the impact of marketing tools on consumers' pre-purchase beliefs. Future research could explore the role of advertising, particularly on social media, and its effect on managing consumers' expectations and achieving profit maximization. Third, cognitive biases may influence consumers' pre-purchase beliefs and impact purchasing decisions. These biases could include anchoring, risk aversion, loss aversion, and mental accounting. Incorporating these biases into the model could provide further insight into consumer behavior and pricing strategies. Finally, to strengthen the credibility of our results, empirical studies could be conducted. For instance, researchers could adopt a case study approach and interview retailers to gain insights into how they determine selling prices, order quantities, and manage consumers' expectations. Additionally, experimental studies could be designed to test whether decision-makers exhibit the same behavior under the conditions specified by our model.

Appendix A: Numerical investigation

In this section, we numerically discuss how reservation utility affects the region of each optimal strategy and how much profit loss can be if retailers ignore or overlook consumers' pre-purchase beliefs. We set the parameters as follows: $c = 3$, $v_0 \in [3, 3.8]$, $\beta = 0.6$, $N \sim N(120, 40^2)$ and $V \sim N(4, 2.5^2)$.

Appendix A.1: The effect of reservation utility

We start with the effect of reservation utility by varying reservation utility $r_b \in \{1.4, 1.6, 1.8\}$. Note that $p_S = 8$ and $p_0 \in \{3.71, 3.43, 3.15\}$ under this setting. Figure 7 presents the critical market shares of BS consumers with varying reservation utility. It is clear that a higher reservation utility reduces the size of the area where selling to S and BS is optimal. Since a

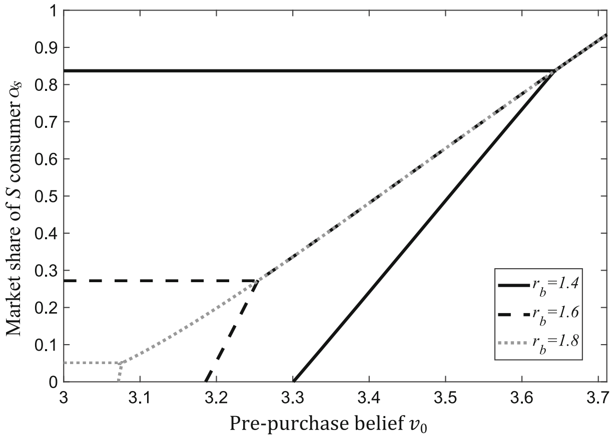


Fig. 7 Optimal strategy with varying reservation utility

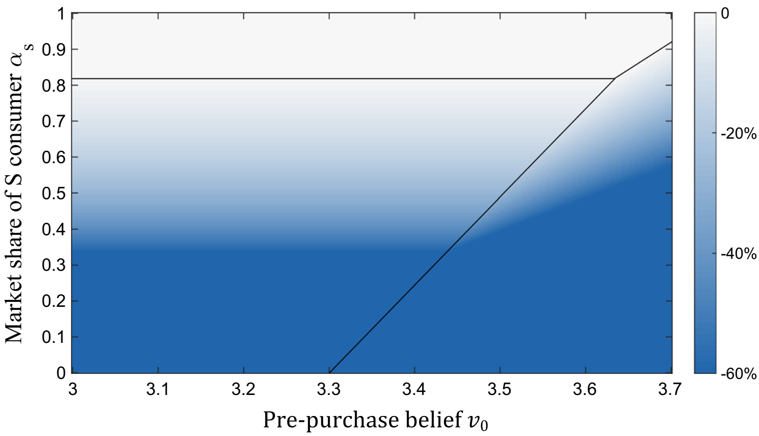


Fig. 8 Profit loss from ignoring pre-purchase belief Δ_{Loss}

bigger price discount has to be offered to BS consumers if the reservation utility increases, selling to S and BS is less likely to be optimal.

Appendix A.2: The consequences of ignoring consumers' pre-purchase beliefs

Next, we investigated the potential profit loss that retailers could face if they ignore or overlook consumers' pre-purchase beliefs. We choose the baseline strategy of "selling to S only" as the benchmark. To examine the profit loss from ignoring consumers' pre-purchase beliefs, we compare the retailer's profit under the optimal strategy with the profit under the "selling to S only" strategy, i.e., $\max\{\Pi_S, \Pi_A, \Pi_{S+BS}\}$ vs. Π_S. Note that the percentage profit loss from ignoring consumers' pre-purchase beliefs is measured by $\Delta_{\text{Loss}} := \frac{\Pi_S - \max\{\Pi_S, \Pi_A, \Pi_{S+BS}\}}{\Pi_S} \times 100\%$. Figure 8 presents the percentage loss from ignoring consumers' pre-purchase beliefs when $r_b = 1.4$.

Not surprisingly, ignoring consumers' pre-purchase beliefs does not bring losses only if "selling to S only" is optimal, i.e., most consumers are purely surplus-driven. However, if pre-belief consumers account for a large proportion of the market, then continuing to use the "selling to S only" strategy will result in a considerable profit loss of up to more than 70%. Moreover, ignoring consumers' pre-purchase beliefs can further exacerbate profit loss if consumers buying decisions are driven by both pre-purchase belief and surplus. For example, when the proportion of surplus-driven consumers is relatively high [low], i.e., α_S=70% [30%], then the maximum profit loss is increased from 7.9% (selling to S and BS) to 31.2% (selling to all) [from 72% to 206%]. This is because the reservation utility demanded by BS consumers further reduces the retailer's profit.

Appendix B Lemma and proofs

Lemma 1 *If the mean pre-belief demand $\mu_D(v_0)$ has an IBE and the market size distribution $F_N(\cdot)$ has an IGFR, then the expected profit $\Pi(Q^*, p^*)$ is quasi-concave in v_0, and there exists a unique consumer pre-purchase belief v_0^* that maximizes the expected profit.*

Proof The first and second derivation of $\Pi(Q^*, p^*)$ with respect to v_0 are

$$\frac{\partial \Pi(Q^*, p^*)}{\partial v_0} = -v_0 f_v(v_0) \int_0^{F_N^{-1}(\frac{v_0-c}{v_0})} x dF_N(x) + \bar{F}_v(v_0)[\frac{c}{v_0} F_N^{-1}(\frac{v_0-c}{v_0}) - \int_0^{F_N^{-1}(\frac{v_0-c}{v_0})} F_N(x)dx], \tag{B.1}$$

$$\frac{\partial^2 \Pi(Q^*, p^*)}{\partial v_0^2} = -v_0 f_v'(v_0) \int_0^{F_N^{-1}(\frac{v_0-c}{v_0})} x dF_N(x) - 2 f_v(v_0)[\frac{c}{v_0} F_N^{-1}(\frac{v_0-c}{v_0}) + \int_0^{F_N^{-1}(\frac{v_0-c}{v_0})} F_N(x)dx] + \frac{c^2 \bar{F}_v(v_0)}{v_0^3 f_N(F_N^{-1}(\frac{v_0-c}{v_0}))}. \tag{B.2}$$

Note that $\frac{\partial \Pi(Q^*,p^*)}{\partial v_0}\Big|_{v_0=c} = 0$ and $\frac{\partial \Pi(Q^*,p^*)}{\partial v_0}\Big|_{v_0=\bar{v}} = \bar{v}[\bar{F}_v(\bar{v})]' \int_0^{F_N^{-1}(\frac{\bar{v}-c}{\bar{v}})} x dF_N(x) < 0$. Further, $\frac{\partial^2 \Pi(Q^*,p^*)}{\partial v_0^2}\Big|_{v_0=c} = \frac{1}{c f_N(0)} > 0$ indicates that there exists at least one solution $v_0^* \in (c, \overline{v}_0)$ such that $\frac{\partial \Pi(Q^*,p^*)}{\partial v_0}\Big|_{v=v_0^*} = 0$. For the uniqueness of v_0^*, we prove $\frac{\partial^2 \Pi(Q^*,p^*)}{\partial v_0^2}\Big|_{v_0=v_0^*} < 0$ in the following.

Since we assume that $\mu_D(v_0)$ is IBE, then we have that $\bar{F}_v(v_0)$ is IBE, and

$$\frac{de}{dv_0} = -\frac{[v_0[\bar{F}_v(v_0)]'' + [\bar{F}_v(v_0)]']\bar{F}_v(v_0) - v_0(\bar{F}_v'(v_0))^2}{\bar{F}_v^2(v_0)} \geq 0,$$

which we can rewrite as

$$[-f_v(v_0)]' \leq \left(\frac{v_0 f_v(v_0)}{\bar{F}_v(v_0)} + 1\right) \frac{f_v(v_0)}{v_0}. \tag{B.3}$$

Then,

$$\left.\frac{\partial^2\Pi(Q^*,p^*)}{\partial v_0^2}\right|_{v=v_0^*} \le -f_v(v_0^*)\big[(\frac{-v_0^* f_v(v_0^*)}{\bar{F}_v(v_0^*)}+1)\int_0^{F_N^{-1}(\frac{v_0^*-c}{v_0^*})} x dF_N(x) + \frac{2c}{v_0^*}F_N^{-1}(\frac{v_0^*-c}{v_0^*})\big] + \frac{c^2\bar{F}_v(v_0^*)}{v_0^{*3} f_N(F_N^{-1}(\frac{v_0^*-c}{v_0^*}))} = \frac{c\bar{F}_v(v_0^*)}{v_0^{*2}\int_0^{F_N^{-1}(\frac{v_0^*-c}{v_0^*})} x dF_N(x)} \cdot A(v_0^*),$$

where

$$A(v_0^*) = -F_N^{-1}(\frac{v_0^*-c}{v_0^*})\left(\int_0^{F_N^{-1}(\frac{v_0^*-c}{v_0^*})} x f_N(x)dx + \frac{c}{v_0^*}F_N^{-1}(\frac{v_0^*-c}{v_0^*})\right) + \frac{c\int_0^{F_N^{-1}(\frac{v_0^*-c}{v_0^*})} x dF_N(x)}{v_0^* f_N(F_N^{-1}(\frac{v_0^*-c}{v_0^*}))}.$$

To complete the proof, we need to show that $A(v_0^*) \le 0$. Let $t = F_N^{-1}(\frac{v_0^*-c}{v_0^*})$ and $r(t) = \frac{f_N(t)}{1-F_N(t)}$. Then, we can rewrite $A(v_0^*)$ as

$$A(t) = -t\left(\int_0^t x dF_N(x) + t(1-F_N(t))\right) + \frac{\int_0^t x dF_N(x)}{r(t)}.$$

Note that $A(0) = 0$ and N has an IGFR that implies that $-\frac{tr'(t)}{r(t)} \le 1$. Thus,

$$A'(t) = -\left(\int_0^t x dF_N(x) + t(1-F_N(t))\right) - t\big(1-F_N(t)\big) + \frac{tf_N(t)r(t) - r'(t)\int_0^t x dF_N(x)}{r^2(t)}$$
$$\le -t\big(1-F_N(t)\big) - \int_0^t x dF_N(x) + \frac{\int_0^t x dF_N(x)}{tr(t)}.$$

Let $B(t) \triangleq -t\big(1-F_N(t)\big) - \int_0^t x dF_N(x) + \frac{\int_0^t x dF_N(x)}{tr(t)}$. Then, we have

$$\lim_{t\to 0} B(t) = \lim_{t\to 0}\frac{\int_0^t x dF_N(x)}{tr(t)} = \lim_{t\to 0}\frac{tf_N(t)}{r(t)+tr'(t)} = 0 \text{ and } B'(t) = -\frac{[tr(t)]'\int_0^t x dF_N(x)}{\big(tr(t)\big)^2}.$$

By the definition of IGFR; that is, $[tr(t)]' \ge 0$, $B'(t) \le 0$, which implies that $B(t) \le 0$ holds. Since $A'(t) \le B(t)$ and $A(0) = 0$, we have $\left.\frac{\partial^2\Pi(Q^*,p^*)}{\partial v_0^2}\right|_{v=v_0^*} \le 0$; that is, $\Pi(Q^*, p^*)$ is quasi-concave in v_0. This completes the proof. □

Proof of Proposition 4.1

Since the highest price that consumers are willing to pay is v_0, the retailer's optimal selling price must satisfy $p^* \le v_0$. Since the market demand $D(v_0)$ is independent of the selling price and the expected profit is increasing in p, the retailer would price the product at v_0

and extract all consumer surplus, i.e., $p^* = v_0$. Differentiating $\Pi(Q, p^*)$ with respect to Q gives

$$\frac{d\Pi(Q, p^*)}{dQ} = p^* - c - p^* F_N(\frac{Q}{\bar{F}_v(v_0)}) \quad \text{and} \quad \frac{d^2\Pi(Q, p^*)}{dQ^2} = -p^* f(\frac{Q}{\bar{F}_v(v_0)}) < 0.$$

Clearly, $\Pi(Q, p^*)$ is concave in Q. Then there is a unique Q^* such that $\frac{d\Pi(Q,p^*)}{dQ}|_{Q=Q^*} = 0$, that is $Q^* = \bar{F}_v(v_0) F_N^{-1}(\frac{v_0-c}{v_0})$. Accordingly, $\Pi(Q^*, p^*) = v_0 \bar{F}_v(v_0) \int_0^{F_N^{-1}(\frac{v_0-c}{v_0})} x dF_N(x)$.

Proof of Proposition 4.2

We omit the proof details for optimal decisions. Here we only prove the monotonicity of p_0. From Equation (4), the first derivation of p_0 with respect to r_b is

$$\frac{dp_0}{dr_b} = \frac{F_v(p_0 + r_b) + 2r_b f_v(p_0 + r_b)}{-1 - 2r_b f_v(p_0 + r_b) + F_v(p_0 + r_b)}.$$

Since $-(1-F_v(p+r_b)) \leq 0$ and $F_v(p+r_b)+2r_b f_v(p+r_b) \geq 0$, we have $\frac{dp}{dr_b} \leq 0$. Replacing v_0 by p_0 in Equation (4), we can find a critical $\hat{r}_b$ such that $U_{BS}(p_0(\hat{r}_b)) = U_{BS}(v_0) = 0$.

Proof of Proposition 5.1

Overpricing (i.e., $p > v_0$) will prevent pre-belief consumers. However, underpricing (i.e., $p \leq v_0$) will attract both types of consumers, but may result in profit loss due to offering too much of a discount for BS consumers. Therefore, we discuss the problem in two cases: $v_0 < p$ and $v_0 \geq p$. For $v_0 < p$, since B consumers never buy in this case, selling to all is identical to selling to BS only. By Proposition 4.2, the optimal decisions and the correspondingly maximal expected profit are $p^* = p_0$, $Q^* = \alpha_{BS} \bar{F}_v(p_0 + r_b) F_N^{-1}(\frac{p_0-c}{p_0})$ and $\Pi_{BS}(p^*, Q^*) = \alpha_{BS} K(p_0, r_b)$. For $v_0 \geq p$, all consumers with pre-purchase beliefs consider buying. By Proposition 4.1, we have $p^* = v_0$, $Q^* = \bar{F}_v(v_0) F_N^{-1}(\frac{v_0-c}{v_0})$ and $\Pi_A(p^*, Q^*) = K(v_0, 0)$. The profit difference between the two selling strategies is

$$\begin{aligned}\Delta\Pi &= \Pi_A - \Pi_{BS} = K(v_0, 0) - \alpha_{BS} K(p_0, r_b) \\ &= v_0 \bar{F}_v(v_0) \int_0^{F_N^{-1}(\frac{v_0-c}{v_0})} x dF_N(x) - \alpha_{BS} p_0 \bar{F}_v(p_0 + r_b) \int_0^{F_N^{-1}(\frac{p_0-c}{p_0})} x dF_N(x).\end{aligned}$$

Taking the first derivation of $\Delta\Pi$ with respect to α_{BS} gives $\frac{d\Delta\Pi}{d\alpha_{BS}} = -K(p_0, r_b) < 0$ which indicates that $\Delta\Pi$ is decreasing in α_{BS}. Note that $\Delta\Pi|_{\alpha_{BS}=0} = K(v_0, 0) > 0$. If $\Delta\Pi|_{\alpha_{BS}=1} = K(v_0, 0) - K(p_0, r_b) > 0$, then $\Delta\Pi \geq 0$ always holds. Otherwise, there exists a critical market share $\tilde{\alpha}_{BS}$ such that $\Delta\Pi(\tilde{\alpha}_{BS}) = 0$. If $\alpha_{BS} \leq \tilde{\alpha}_{BS}$, then $\Delta\Pi \geq 0$; otherwise $\Delta\Pi \leq 0$. To complete the proof, we next verify the sign of $\Delta\Pi|_{\alpha_{BS}=1}$.

It follows from Lemma 1 that $K(v_0, 0)$ is quasi-concave in v_0. This implies that $\Delta\Pi|_{\alpha_{BS}=1} = K(v_0, 0) - K(p_0, r_b)$ is quasi-concave in v_0. Note that, by Proposition 4.2, selling to BS exists only if $p_0 \geq v_0$ for any given v_0. Therefore, to ensure both strategies exist, the admissible range of v_0 should be $[c, p_0]$. Since $\Delta\Pi|_{\alpha_{BS}=1}(v_0 = c) = -K(p_0, r_b) < 0$ and $\lim_{v_0 \to p_0} \Delta\Pi|_{\alpha_{BS}=1}(v_0) = K(p_0, 0) - K(p_0, r_b) \geq 0$, there exists a unique $\tilde{v}_0$ such that $\Delta\Pi|_{\alpha_{BS}=1}(\tilde{v}_0) = 0$. If $v_0 \leq \tilde{v}_0$, then $\Delta\Pi|_{\alpha_{BS}=1} \leq 0$; otherwise, $\Delta\Pi|_{\alpha_{BS}=1} \geq 0$.

Proof of Proposition 6.1

(a) $p_0 \le v_0^L \le v_0^H$

The optimal decisions of high pricing are $p^* = v_0^H$ and $Q^* = \alpha_H \bar{F}_v(v_0^H) F_N^{-1}(\frac{v_0^H - c}{v_0^H})$. For low pricing, we have $p^* = v_0^L$ and $Q^* = [\alpha_H \bar{F}_v(v_0^H) + \alpha_L \bar{F}_v(v_0^L)] F_N^{-1}(\frac{v_0^L - c}{v_0^L})$. Correspondingly, the maximum profits of high and low pricing are $\Pi_H = \Pi_{HB} + \Pi_{HBS} = \alpha_H K(v_0^H, 0)$ and $\Pi_A = \Pi_{HB} + \Pi_{HBS} + \Pi_{LB} + \Pi_{LBS} = \alpha_H K(v_0^L, \Delta_{v0}) + \alpha_L K(v_0^L, 0)$, respectively. The profit difference between the two selling strategies is

$$\Delta\Pi = \Pi_A - \Pi_H = \alpha_H (K(v_0^L, \Delta_{v0}) - K(v_0^L, 0) - K(v_0^H, 0)) + K(v_0^L, 0).$$

Since $K(v_0^L, \Delta_{v0}) \le K(v_0^L, 0)$, it is clear that $\Delta\Pi$ is decreasing in α_H. Note that $\Delta\Pi|_{\alpha_H=0} > 0$. So, there must exist a critical $\hat{\alpha}_H^0$ such that $\Delta\Pi(\hat{\alpha}_H^0) = 0$. If $\alpha_H \le \hat{\alpha}_H^0$, then $\Delta\Pi \ge 0$; otherwise, $\Delta\Pi \le 0$.

(b) $v_0^L \le p_0 \le v_0^H$

By comparing the profits of any two strategies, we have the following results.

(I) (Selling to All vs. Selling to H) See part (a).

(II) (Selling to All vs. Selling to H and LBS) There exists a critical market share $\hat{\alpha}_H^1$ such that $\Pi_{H+LBS}(\hat{\alpha}_H^1) = \Pi_A(\hat{\alpha}_H^1)$. If $\alpha_H \le \hat{\alpha}_H^1$, then $\Pi_A \ge \Pi_{H+LBS}$; otherwise, $\Pi_A \le \Pi_{H+LBS}$.

(III) (Selling to H vs. Selling to H and LBS) There exists a critical market share of high-belief consumers $\hat{\alpha}_H^2$ such that $\Pi_{H+LBS}(\hat{\alpha}_H^2) = \Pi_H(\hat{\alpha}_H^2)$. If $\alpha_H \le \alpha_H^2$, then $\Pi_{H+LBS} \ge \Pi_H$; otherwise, $\Pi_H \ge \Pi_{H+LBS}$.

Note that $K(v_0^H, 0) \ge K(p_0, v_0^H - p_0) \ge K(v_0^L, \Delta_{v0})$ for $v_0^L < p_0 \le v_0^H$. So we have

$$\frac{d\hat{\alpha}_H^1}{d\alpha_{BS}} = \frac{K(p_0, r_b)(K(v_0^L, \Delta_{v0}) - K(p_0, v_0^H - p_0))}{[K(p_0, v_0^H - p_0) + K(v_0^L, 0) - K(v_0^L, \Delta_{v0}) - \alpha_{BS} K(p_0, r_b)]^2} \le 0,$$
$$\frac{d\hat{\alpha}_H^2}{d\alpha_{BS}} = \frac{K(p_0, r_b)(K(v_0^H, 0) - K(p_0, v_0^H - p_0))}{[K(v_0^H, 0) + \alpha_{BS} K(p_0, r_b) - K(p_0, v_0^H - p_0)]^2} \ge 0.$$

Further, we have $\hat{\alpha}_H^2|_{\alpha_{BS}=0} = 0$, $\hat{\alpha}_H^2|_{\alpha_{BS}=1} = \frac{K(p_0,r_b)}{K(p_0,r_b)+K(v_0^H,0)-K(p_0,v_0^H-p_0)} < 1$, and

$$\begin{aligned}
\hat{\alpha}_H^1|_{\alpha_{BS}=0} &= \frac{K(v_0^L, 0)}{K(p_0, v_0^H - p_0) + K(v_0^L, 0) - K(v_0^L, \Delta_{v0})} \\
&\ge \frac{K(v_0^L, 0)}{K(v_0^H, 0) + K(v_0^L, 0) - K(v_0^L, \Delta_{v0})} = \hat{\alpha}_H^0, \\
\hat{\alpha}_H^1|_{\alpha_{BS}=1} &= \frac{K(v_0^L, 0) - K(p_0, r_b)}{K(p_0, v_0^H - p_0) - K(v_0^L, \Delta_{v0}) + K(v_0^L, 0) - K(p_0, r_b)} < 1.
\end{aligned}$$

Therefore, $\hat{\alpha}_H^1$ and $\hat{\alpha}_H^2$ intersect with $\hat{\alpha}_H^0$ at $\hat{\alpha}_{BS}^1$ and $\hat{\alpha}_{BS}^2$, respectively. Further, it is easy to verify that $\hat{\alpha}_{BS}^1 = \hat{\alpha}_{BS}^2 = \frac{K(v_0^L,0)}{K(p_0,r_b)} \cdot \frac{K(p_0,v_0^H-p_0)-K(v_0^H,0)}{K(v_0^L,\Delta_{v0})-K(v_0^H,0)}$. This implies that three critical market shares have a common intersection. Therefore, selling to all is best if $\alpha_H \le \min\{\hat{\alpha}_H^0, \hat{\alpha}_H^1\}$; selling to H is best if $\alpha_H \ge \max\{\hat{\alpha}_H^0, \hat{\alpha}_H^2\}$, otherwise selling to H and LBS is best.

(c) $v_0^L \le v_0^H \le p_0$

By comparing the profits of any two strategies, we have

(I) (Selling to All vs. Selling to BS) There exists a critical market share of H consumers $\breve{\alpha}_H^0$ such that $\Pi_A(\breve{\alpha}_H^0) = \Pi_{BS}$. If $\alpha_H \le \breve{\alpha}_H^0$, then selling to all consumers is best; otherwise, selling to BS consumers is best.

(II) (Selling to All vs. Selling to H and LBS consumer) There exists a critical market share of H consumers $\breve{\alpha}_H^1$ such that $\Pi_A(\breve{\alpha}_H^1) = \Pi_{H+LBS}(\breve{\alpha}_H^1)$. If $\alpha_H \le \breve{\alpha}_H^1$, then selling to all consumers is best; otherwise, selling to H and LBS is best.

(III) (Selling to H and LBS vs. Selling to BS) There exists a critical market share of H consumers $\breve{\alpha}_H^2$ such that $\Pi_{H+LBS}(\breve{\alpha}_H^2) = \Pi_{BS}$. If $\alpha_H \ge \breve{\alpha}_H^2$, then selling to H and LBS is best; otherwise, selling to BS consumers is best.

Note that $K(v_0^H, 0) \ge K(v_0^L, \Delta_{v0})$, $K(v_0^H, 0) \ge K(v_0^H, r_b)$ and $K(v_0^L, 0) \ge K(v_0^L, \Delta_{v0})$. If critical market shares exist, then we have $\frac{d\hat{\alpha}_H^0}{d\alpha_{BS}} \le 0$,

$$\frac{d\breve{\alpha}_H^1}{d\alpha_{BS}} = \frac{K(v_0^H, r_b)(K(v_0^L, \Delta_{v0}) - K(v_0^H, 0))}{[K(v_0^H, 0) + K(v_0^L, 0) - \alpha_{BS}K(v_0^H, r_b) - K(v_0^L, \Delta_{v0})]^2} \le 0,$$

$$\frac{d\breve{\alpha}_H^2}{d\alpha_{BS}} = \frac{K(v_0^H, 0)(K(p_0, r_b) - K(v_0^H, r_b))}{[K(v_0^H, 0) - \alpha_{BS}K(v_0^H, r_b)]^2} \ge 0.$$

Note that $\breve{\alpha}_H^0|_{\alpha_{BS}=0} \ge 1$, $\breve{\alpha}_H^1|_{\alpha_{BS}=0} \ge 0$ and $\breve{\alpha}_H^2|_{\alpha_{BS}=0} = 0$. Further, it is easy to verify that $\breve{\alpha}_H^0$, $\breve{\alpha}_H^1$ and $\breve{\alpha}_H^2$ intersect at the same point $\breve{\alpha}_{BS}$, i.e., there is a critical $\breve{\alpha}_{BS}$ such that $\breve{\alpha}_H^0(\breve{\alpha}_{BS}) = \breve{\alpha}_H^1(\breve{\alpha}_{BS}) = \breve{\alpha}_H^2(\breve{\alpha}_{BS})$.

Proof of Proposition 6.2

By comparing the profits of any two strategies, we have

(I) (Selling to S vs. Selling to All) The profit difference between selling to S and selling to all is $\Delta\Pi = \Pi_S - \Pi_A = \alpha_S K(p_S, 0) - K(v_0, 0)$. Clearly, $\Delta\Pi$ is increasing in α_S. Note that $\Delta\Pi|_{\alpha_S=0} < 0$ and $\Delta\Pi|_{\alpha_S=1} = K(p_S, 0) - K(v_0, 0)$. If $K(p_S, 0) - K(v_0, 0) \le 0$, then $\Delta\Pi < 0$ always holds; otherwise, there exists a critical market share $\hat{\alpha}_S^0$ such that $\Delta\Pi(\hat{\alpha}_S^0) = 0$. If $\alpha_S \ge \hat{\alpha}_S^0$, then selling to S consumers only is best; otherwise, selling to all consumers is best.

(II) (Selling to S and BS vs. Selling to All) The profit difference between selling to S+BS and selling to all is

$$\Delta\Pi = \Pi_{S+BS} - \Pi_A = \alpha_S K(p_0, 0) + \beta(1 - \alpha_S)K(p_0, r_b) - K(v_0, 0).$$

Taking the first derivation of $\Delta\Pi$ with respect to α_S gives that $\frac{d\Delta\Pi}{d\alpha_S} = K(p_0, 0) - \beta K(p_0, r_b) > 0$ holds for any given β, which indicates that $\Delta\Pi$ is increasing in α_S. Note that $\Delta\Pi|_{\alpha_S=1} = K(p_0, 0) - K(v_0, 0)$ and $\Delta\Pi|_{\alpha_S=0} = \beta K(p_0, r_b) - K(v_0, 0)$. If $(K(p_0, 0) - K(v_0, 0))(\beta K(p_0, r_b) - K(v_0, 0)) \ge 0$, then $\Delta\Pi > 0$ or $\Delta\Pi < 0$ always holds; otherwise, there exists a critical market share $\hat{\alpha}_S^1$ such that $\Delta\Pi(\hat{\alpha}_S^1) = 0$. If $\alpha_S \ge \hat{\alpha}_S^1$, then selling to S and BS is best; otherwise selling to all is best.

(III) (Selling to S only vs. Selling to S and BS) The profit difference between selling to S and selling to S+BS is

$$\Delta\Pi = \Pi_S - \Pi_{S+BS} = \alpha_S K(p_S, 0) - \alpha_S K(p_0, 0) - \beta(1-\alpha_S)K(p_0, r_b)$$
$$= \alpha_S[K(p_S, 0) - K(p_0, 0) + \beta K(p_0, r_b)] - \beta K(p_0, r_b).$$

Taking the first derivation of $\Delta\Pi$ with respect to α_S gives $\frac{d\Delta\Pi}{d\alpha_S} = K(p_S, 0) - K(p_0, 0) + \beta K(p_0, r_b) > 0$, which indicates that $\Delta\Pi$ is increasing in α_S. Note that $\Delta\Pi|_{\alpha_S=1} = K(p_S, 0) - K(p_0, 0)$ and $\Delta\Pi|_{\alpha_S=0} = -\beta K(p_0, r_b) \leq 0$. If $K(p_S, 0) - K(p_0, 0) \leq 0$, then $\Delta\Pi < 0$ always holds; otherwise, there exists a critical market share $\hat{\alpha}_S^2$ such that $\Delta\Pi(\hat{\alpha}_S^2) = 0$. If $\alpha_S \geq \hat{\alpha}_S^2$, then selling to S only is best; otherwise, selling to S and BS is best.

Note that $\hat{\alpha}_S^0|_{v_0=c} = 0$, $\hat{\alpha}_S^1|_{v_0=c} < 0$, and $\hat{\alpha}_S^i$ exists only if $K(p_s, 0) \geq K(p_0, 0) \geq K(v_0, 0)$ where $i \in \{1, 2, 3\}$ and $v_0 \leq p_0 \leq p_S$. By Lemma 1, we have $\hat{\alpha}_S^0$ and $\hat{\alpha}_S^1$ are quasi-concave in v_0 and $\hat{\alpha}_S^2$ is independent with v_0. Then, it is easy to verify that there is a critical $\hat{v}_0$ such that $\hat{\alpha}_S^0(\hat{v}_0) = \hat{\alpha}_S^1(\hat{v}_0) = \hat{\alpha}_S^2$, i.e., $\hat{v}_0$ satisfies $K(\hat{v}_0, 0) = \frac{\beta K(p_S,0)K(p_0,r_b)}{K(p_S,0)-K(p_0,0)+\beta K(p_0,r_b)}$. Therefore, selling to all is best if $\alpha_S \leq \hat{\alpha}_S^0$ for $v_0 \geq \hat{v}_0$ or $\alpha_S \leq \hat{\alpha}_S^1$ for $v_0 \leq \hat{v}_0$; selling to S is best if $\hat{\alpha}_S^1 \leq \alpha_S \leq \hat{\alpha}_S^2$; otherwise, selling to S and BS is best.

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