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Optimal pricing strategy: How to sell to strategic consumers?

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ABSTRACT

Technological advances are preparing consumers to plan their purchases strategically. Selling to strategic consumers at a fixed price forgoes the profit from salvaging inventory, whereas high-low pricing, as a ubiquitous pricing strategy, is costly due to the offered markdown discount. This research explores the overall impact of consumer's strategic buying behaviour on a pricing strategy, and identifies conditions where fixed pricing, strategic high pricing, or high-low pricing is the best approach by analytically comparing the profits of the three pricing strategies. Our results show that high-low pricing is appropriate only if the offered markdown discount is relatively small. If strategic consumers have a small population and the needed markdown discount is relatively large, retailers can ignore strategic buying behaviour and sell products at a fixed price. Our results emphasize that the markdown discount for clearance sales and the market structure of heterogeneous consumers play vital roles in determining the optimal pricing strategy.

1. Introduction

Pricing is the most important lever that a retailer pulls. Retailers have spent decades defining pricing strategies. Three prominent pricing strategies are high pricing (e.g. premium pricing, examples include iPhone and Tesla's flagship products and Hermès leather goods), low pricing (e.g. everyday low price, examples include Walmart and Trader Joe's), and high-low pricing (e.g. premium fashion brands includes Michael Kors, Ralph Lauren) emphasize high profit margins, higher sales volume, and both profit margin and sales volume, respectively. Different with high pricing and low pricing, which set a fixed selling price, the price under high-low pricing can alter between "high" and "low" over a selling season. In other words, high-low pricing is a pricing strategy wherein a company initially charges high prices and periodically offers consumers lower prices through promotions or clearances to attract customers in the broader market. The high-low pricing strategy, which was launched in the 1920s, is ubiquitous and has been extensively used in a variety of industries, notably fashion goods and short-life-cycle products, such as Macy's (retailer), Adidas and Nike (speciality company). Over 75% of sales volumes and 40% percent of products were sold at sale prices (Kaufmann et al., 1994). High-low pricing benefits retailers and yields substantial profits in the following three aspects. First, high-low pricing generates additional sales and reaches price-sensitive consumers through lowered prices since a retailer can adopt price discrimination among consumers who perceive and respond to price sensitivity. Furthermore, markdown (offering lower prices) is profitable when consumers are heterogeneous in valuations and patience (Su, 2007). Second, markdown is an important way to clean up after errors are made in ordering and pricing, such as demand forecasting errors, estimating errors in consumers' willingness to pay, among others. Finally, as the product's value may decrease with time, the price should be lowered when the product losses its popularity, otherwise consumers will not be compelled to buy it.

As everything is two sided, high-low pricing harms retailers by offering markdown discounts. On one hand, as Adida and Özer (2019) commented "While markdowns are common, they have frequently been characterized as a wasteful practice". Markdown was the result of "bad" inventory or pricing decisions. Offering (big) discounts to eliminate operational mistakes may neither benefit retailers nor manufacturers. One the other hand, although markdown generates additional sales, a retailer runs the risk of losing money if price-sensitive consumers only purchase the discounted item (more consumers have become bargain-hunting). There is a growing concern that retailers are training consumers to buy only when the product is on deep sale (Reagan, 2015). Especially, in today's online-retailing era, discerning consumers are capable of spotting items that are priced lower in other online stores, and will buy only low-priced items and avoid those priced higher. Moreover, a high-low pricing strategy is fraught with the risk of

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encouraging consumers to wait for a sale. Many retailers are finding that consumers will anticipate future discounts and forego purchasing until markdowns starts. Consumers who behave in this manner are referred to as strategic or rational consumers (Cachon and Swinney, 2009).

Different from regular or myopic consumers who accept retailers full-price sales, strategic consumers decide when to buy based on a trade-off between future purchase at a discounted price and immediate purchase without any discounts. The presence of strategic consumers can significantly affect retailer's profitability, for instance, the potential loss of revenue can reach about 20% (Aviv and Pazgal, 2008). Ignoring strategic behaviour leads the retailer to order too much, thereby resulting in a deep discount to markdown prices. If consumers can anticipate the big discount, they are more likely to wait for clearance sales. In other words, high-low pricing becomes worse off in the presence of strategic consumers. To maintain a profitable business, retailers attempt to reduce profit losses through quick response (the ability to procure additional inventory, Cachon and Swinney 2009), selling in advance (Li and Zhang, 2013; Lim and Tang, 2013; Prasad et al., 2011), responsive pricing (Levina et al., 2009; Cachon and Swinney, 2009; Levin et al., 2010; Ovchinnikov and Milner, 2012; Wu et al., 2015; Papanastasiou and Savva, 2017; Aviv et al., 2019), pre-announced pricing (Aviv and Pazgal, 2008; Mersereau and Zhang, 2012; Correa et al., 2016), price matching (Lai et al., 2010), and fixed pricing (Su and Zhang, 2008, Su, 2010a,b, Lim and Tang, 2013).

In the present digital era, modern consumers are educated and sophisticated. In a controlled laboratory environment, up to 79% of customers exhibited strategic buying behaviour (Osadchiy and Bendoly, 2015). Due to consumers' strategic behavior, Cachon and Swinney (2009) suggested that retailers should avoid committing to a price path over the season in the presence of strategic consumers. Some experts advocates selling expensive with a small quantity rather than offering price markdowns (Smith, 2014; Reagan, 2015; Ang, 2016). Therefore, some commonly used pricing strategies (e.g. high-low pricing) may no longer be profitable, especially when challenged by a greater number of unknown consumer responses. Echoing the experts' suggestions, several brands that vary across price induce and encourage consumers to pay full price. These brands include luxury brands (Louis Vuitton, Tiffany, Hermès and Chanel), premium brands (e.g., Everlane, Kent Wang, Apple), valuable brands (e.g., Huawei, Xiaomi). The methods they employ include never markdown and offering a very tiny discount to very few (loyal) consumers, which are referred as fixed price selling and strategic high price selling.

From the perspective of supply chain management, high-low pricing and other more complex dynamic pricing strategies employed by retailers pose challenges to supply chain coordination and significantly increase contract complexity. To achieve win-win situation, supply chain members should collaborate on designing a simpler contract and decrease contract complexity to make the contract can be easily implemented (Voeth and Herbst, 2006; Shen et al., 2019). At this point, retailers are also motivated by supply chain members to revisit their retailing strategies. Some interesting and unexplored questions remain to be answered. *Compared with the high-low pricing strategy, is a simple fixed pricing strategy better off? How can strategic consumers be motivated to purchase early rather than wait for the markdown? How does market structure affect the optimal pricing strategy, especially when part of strategic consumers are new consumers?*

To answer the above questions, this study explores the overall effects of strategic buying behaviour on pricing strategies, and identifies conditions where fixed pricing, strategic high pricing, and high-low pricing are best. Our results show that if the strategic market size is relatively small and the required markdown discount is relatively large, then retailers should ignore consumers' strategic buying behaviour and sell products at a fixed price only. Otherwise, the retailer should focus on the impact of strategic buying behavior on the choice of the selling strategy. If the strategic market size is relatively big, then offering a small discount to induce more strategic consumers to make purchases immediately (i.e., strategic high pricing) is appropriate; alternatively, inducing strategic consumers to wait by offering a big discount is best because the retailer can set a higher price for myopic consumers and benefit from additional sales from selling to bargain hunters. Our results stress that the markdown discount for clearance sales and the market structure of heterogeneous consumers play vital roles in determining the optimal strategy.

The remainder of this paper is organized as follows. Section 2 reviews the related literature, and Section 3 introduces the model settings. Section 4 presents the fixed pricing strategy. Section 5 studies strategic high pricing and compares it with fixed pricing. Section 6 addresses high-low pricing and compares three pricing strategies. Section 7 provides numerical studies to examine how varying market conditions affect a retailer's optimal strategy and the impact of the different pricing strategies on the required capacity and consumer welfare. Section 8 concludes the paper.

2. Literature review

In this section, we review the literature from two aspects: pricing strategy and strategic buying behaviour in Sections 2.1 and 2.2, respectively. We summarize our contributions in Section 2.3.

2.1. Pricing strategy

In operations management, we refer interested readers to Bai et al. (2019) for a detailed review of the literature on the newsvendor pricing model. By incorporating consumer behaviour, the study of pricing strategy starts from myopic consumers (e.g. Gallego and van Ryzin, 1994). However, in the presence of strategic consumers, Talluri and van Ryzin (2004) argue that failure to account for strategic customer behaviour could significantly reduce expected revenues from dynamic pricing. Recent research on strategic buying behaviour has developed several strategies to counteract strategic buying behaviour, which include responsive pricing (e.g. Levin et al., 2010; Cachon and Swinney, 2009; Ovchinnikov and Milner, 2012; Wu et al., 2015), pre-announced pricing (e.g. Aviv and Pazgal, 2008), fixed pricing (e.g. Su and Zhang, 2008, Su, 2010a,b, Lim and Tang, 2013), and price matching (e.g. Altug and Aydinliyim, 2016). More specifically, Levin et al. (2010) show that responsive pricing may be ineffective in counteracting strategic buying behaviour. Recently, Aviv and Pazgal (2008) show that pre-announced pricing could outperform responsive pricing in mitigating strategic buying behaviour. Su and Zhang (2008) show that fixed pricing strategy could improve a firm's profit over a markdown strategy, and indicate that commitment to fixed pricing strategy may not be credible.

Additionally, some papers analyse various aspects of the high-low pricing (markdown) strategy with strategic consumers, including multi-unit customer demand (e.g. Elmaghraby et al., 2008), pre-announced markdown with reservations (e.g. Elmaghraby et al., 2009; Osadchiy and Vulcano, 2010; Surasvadi et al., 2017), continuously declining consumer valuations (e.g. Aviv and Pazgal, 2008; Lai et al., 2010; Aviv et al., 2019), consumer valuation uncertainty and/or heterogeneity (e.g. Zhang and Cooper, 2008; Prasad et al., 2011; Kremer et al., 2017; Wu et al., 2019), and heterogeneous consumer populations (e.g. Su and Zhang, 2008; Cachon and Swinney, 2009; Wu et al., 2021).

2.2. Strategic buying behaviour

The study on pricing with strategic consumers starts from the economic work of Coase (1972) who shows that a monopoly retailer's profit will be negatively influenced if consumers are strategic. Since then, strategic buying behaviour is empirically confirmed from sales of different products, such as digital products (Nair, 2007), durable goods (Chevalier and Goolsbee, 2009), air tickets (Li and Yu, 2014), and fashion products (Aviv et al., 2019; Yuan and Shen, 2019; Shen et al., 2020). As strategic consumers prefer to buy later at cheaper prices, the literature demonstrates that firms will suffer from strategic buying behaviour (e.g. Stokey, 1979; Besanko and Winston, 1990; Su, 2007; Aviv et al., 2019).

Identifying tactics and strategies to counteract the adverse impact of strategic consumers is a key question (Wei and Zhang, 2018). An early deterministic model of dynamic pricing with strategic consumers is presented in Besanko and Winston (1990). Aviv and Pazgal (2008) study the optimal pricing of fashion products in the presence of strategic consumers under two different price discount strategies: inventory-contingent discounting and announced fixed-discount. They show that fixed discounting may outperform contingent pricing. Several studies (e.g. Liu and van Ryzin, 2008; Zhang and Cooper, 2008; Cachon and Swinney, 2009; Dong and Wu, 2019) examine two-period pricing models with strategic consumers. More specifically, Liu and van Ryzin (2008) use quantity decisions (not pricing) to sell in advance. Zhang and Cooper (2008) consider the option of restricting product availability in the second period. Since sellers may not have ability to make price commitment, dynamic pricing is widely used in the real business. Cachon and Swinney (2009) show that quick response can effectively reduce profit loss by strategic consumers. Furthermore, they show that dynamic pricing is better than committing to a markdown price. However, dynamic pricing drives strategic consumers to learn, wait and predict future discounts. Ovchinnikov and Milner (2012) show that a seller benefits from markdown selling in the long run. With considering that consumers may anchor their price estimations, Wu et al. (2015) propose a consumer's heuristic model in estimating markdown prices and show that the reference and dynamic prices have steady state distribution. Dong and Wu (2019) show that dynamic pricing strategy is profitable if strategic consumers have a relatively large proportion in the market. When consumers incur search costs, Cachon and Feldman (2015) show that the discount-frequently strategy is better than other strategies, especially if no price commitment is made, and "over-ordering" to signal inventory availability is worse off. We refer interested readers to Wei and Zhang (2018) for a detailed review of the studies on strategic buying behaviour in operations management. Moreover, most studies assume that consumers are heterogeneous. They consider that a market consists of different type of consumers, namely myopic consumers, strategic consumers, and bargain-hunters (e.g. Cachon and Swinney, 2009). Some studies have noticed that the market structure may play an important role in determining which pricing strategy is best. For example, Lai et al. (2010) find that when the fraction of strategic consumers is not too small, a price matching strategy may significantly improve the firm's profit.

The formulation of the strategic buying behaviour is based on rational expectations (RE) equilibrium which was first adopted by Su and Zhang (2008). RE equilibrium (Muth, 1961; Stokey, 1981) which characterizes the outcomes of games between sellers and consumers has been widely employed to study consumer behaviours. Based on RE equilibrium, follow-up studies have examined other consumer behaviours and studied the corresponding retail strategy. These consumer behaviours include risk aversion (Ma et al., 2019), loss aversion (Wu et al., 2021), disappointment aversion (Xu and Duan, 2020), strategic buying (Su and Zhang, 2008; Cachon and Swinney, 2009), conspicuous buying (Tereyağoğlu and Veeraraghavan, 2012; Shen et al., 2020), regret (Nasiry and Popescu, 2012), speculator (Lim and Tang, 2013), return (Wu et al., 2019), among others.

In summary, the operations literature mainly focuses on mitigating strategic consumer behaviour but does not consider the potential benefits from selling to strategic consumers. Furthermore, most literature assumes that selling strategy is already known by all strategic consumers, however, new consumers wait to be informed and then make purchasing decision.

2.3. Contribution

This paper differs from the existing literature in three ways. First, most studies (e.g. Cachon and Swinney, 2009; Correa et al., 2016) focusing on the profitability of the high-low pricing strategy consider that selling prices are pre-announced or price guaranteed mechanisms. They show that the high-low pricing strategy may be costly and could hurt retailers when part of consumers are strategic. Different from the extant research focusing on a single selling season, our study is a first step on the profitability of the high-low pricing strategy by announcing a fixed discount. After comparing the profits under different pricing strategies, our analysis leads to a new understanding about the profitability of selling to strategic consumers. Second, although some studies (Fay and Xie, 2010; Prasad et al., 2011; Lim and Tang, 2013) considered to mitigate the strategic behaviour and exploit consumer valuation uncertainty by selling in advance or selling probabilistic products, we discuss the profitability of inducing strategic consumers to buy a deterministic product at a list (full) price in the regular season. Third, although some studies (e.g. Cachon and Swinney, 2009) have characterized consumers' strategic waiting behaviour in the presence of potential markdown discount, we include such waiting behaviour under the fixed pricing strategy when strategic consumers are unaware of whether there exists a markdown sale. This gives new insights into the profitability of fixed pricing.

3. Problem setting

For model formulation, we consider a newsvendor problem in a market where consumers show different purchasing behaviours. The details of consumer setting and retailer setting are explained in Sections 3.1 and 3.2, respectively. Table 1 lists all notations of this paper.

3.1. Consumer setting

For a product, consumer valuation is the maximum value that a consumer is willing to pay. Since it is private information of the consumers themselves and cannot be estimated accurately by retailers, consumer valuation V is assumed to be uncertain. Note that consumer valuation uncertainty is ubiquitous for online selling and selling a newly released product. Valuations can differ across consumers and are affected by many factors (e.g. limited information, personal feeling (Zhao and Stecke, 2010)). To make the problem tractable, the same type of consumers are considered to be identical. Since consumers behave differently, in line with Cachon and Swinney (2009), we classify heterogenous consumers into three types: strategic, myopic and bargain-hunting.

Strategic consumers potentially consider buying during a markdown selling period, while myopic consumers do not take this into account. Since part of strategic consumers are aware of the potential discount

Table 1
Model notation.

p (p_0)	selling price per unit in season 1 (season 0);
c	cost per unit;
$V(V_b)$	product valuation of myopic and strategic (bargain-hunting) consumers which is defined on $[\underline{V}, \overline{V}]$ and has a mean μ_v (μ_b), a standard deviation σ_v (σ_b), a CDF (cumulative distribution function) $F_v(\cdot)$ ($F_b(\cdot)$) and a PDF (probability density function) $f_v(\cdot)$ ($f_b(\cdot)$), where $\mu_b \leq \mu_v$ and $\sigma_b \leq \sigma_v$;
U	consumer's expected utility;
λ	perceived availability risk of strategic consumers from markdown buying, $\lambda \in [0, 1]$;
N_s	number of strategic consumers which is normally distributed and has a CDF $F(\cdot)$ and a PDF $f(\cdot)$, i.e., $N_s \sim N(\mu_s, \sigma_s^2)$;
$N_m(N_b)$	number of myopic (bargain-hunter) consumers which is deterministic;
D	demand in season 1;
$D_m(D_s)$	myopic (strategic) demand in season 1;
I	a start-up inventory level in season 0;
Q	order quantity for strategic demand in season 1;
Q^{Σ}	total order quantity;
$1-\alpha$	markdown discount in percentage where $\alpha \in [\underline{\alpha}, \overline{\alpha}]$.

buying opportunity, we further classify strategic consumers into two types: existing and new. Note that existing strategic consumers are referred to consumers who have enough shopping experience at a certain store, e.g., they know the selling strategy of existing products of similar brands, and roughly know the start time of markdown selling of existing products. New strategic consumers do not have such a purchasing experience. If the retailer never offers a markdown price in the new product introduction stage (season 0), then existing strategic consumers immediately buy a product with a non-negative surplus in the product/brand maturity stage (season 1) and new strategic consumers never buy because they always choose to wait for a discount until the end of the selling season or stockout. If the retailer offers a price discount in season 0 which signals new strategic consumers a potential markdown buying opportunity, then all strategic consumers choose to wait or buy immediately by trading-off the surpluses between buying immediately and waiting. Bargain hunters, who have a relatively low product valuation, never buy at full price, that is, they only consider buying during a markdown period. Therefore, we assume that bargain hunters have a lower average valuation and are associated with a lower valuation risk, that is, $\mu_b \leq \mu_v$ and $\sigma_b \leq \sigma_v$. Furthermore, we let N_m, N_s, and N_b be the number of myopic, strategic and bargain-hunting consumers, respectively. The fraction of existing strategic consumers is denoted by $\beta \in [0, 1]$. To make the problem tractable, N_m and N_b are assumed to be the given constants, and N_s is a normally distributed random variable, namely $N_s \sim N(\mu_s, \sigma_s^2)$. Note that the estimation of a particular (e.g., strategic) market size has been carried out in empirical studies (e.g. Li and Yu, 2014) and laboratory experiments (e.g. Osadchiy and Bendoly, 2015).

Myopic consumers (bargain hunters) make a purchase if their surplus is non-negative. The corresponding expected utilities of myopic consumers and bargain-hunters are

$$U_m(p) \quad = \quad E(V-p)^+ = \mu_v - p + \int_{\underline{V}}^{p} F_v(x)dx, \tag{1}$$

$$U_b(p) \quad = \quad E(V_b-\alpha p)^+ = \mu_b - \alpha p + \int_{\underline{V}}^{\alpha p} F_b(x)dx. \tag{2}$$

Different from myopic consumers and bargain hunters who only decide whether to buy, strategic consumers need to further determine when to make purchases, that is, they react strategically by optimizing the purchase timing. If they make buying decisions immediately (at a high/full price), then they are identical with myopic consumers, that is, $U_s^H(p) = U_m(p)$. If they buy late (at a low/discounted price), then their expected surplus is

$$U_s^L(p,\alpha) = \lambda E(V-\alpha p)^+ = \lambda\left(\mu_v - \alpha p + \int_{\underline{V}}^{\alpha p} F_v(x)dx\right), \tag{3}$$

where $\lambda \in [0, 1]$ represents the availability risk, since strategic consumers who choose to wait cannot assuredly obtain the product. In line with Wu et al. (2019, 2021), we assume that the availability risk is exogenously given because it can only be perceived by the consumers themselves, while inventory level and replenishment policy are the retailer's private information.

To maximize individual expected surplus, a strategic consumer chooses between buying now or buying late. There exists a critical markdown discount $\widehat{\alpha}$ such that both choices are indifferent, that is, $U_s^H(p) = U_s^L(p,\widehat{\alpha})$ or

$$\mu_v - p + \int_{\underline{V}}^{p} F_v(v)\,dv \;= \lambda\left(\mu_v - \widehat{\alpha}p + \int_{\underline{V}}^{\widehat{\alpha}p} F_v(v)dv\right). \tag{4}$$

A strategic consumer buys immediately if and only if $U_s^H(p) \geq U_s^L(p,\alpha)$ or $\widehat{\alpha} \leq \alpha \leq \overline{\alpha}$ and $U_s^H(p) \geq 0$; otherwise, he/she buys during the final clearance if $U_s^L(p,\alpha) \geq 0$. We remark that strategic consumers may be insensitive to a very small discount; therefore, we assume that the markdown discount has a lower bound $1-\overline{\alpha}$ such that consumers have responses to the offered discount.

3.2. Retailer setting

A retailer sells new designs of homogeneous products of a new brand every selling season. The new brand/products has two development stages: introduction and maturity. To make the problem tractable, we treat all periods in each stage as a single period, and use two seasons (the brand introduction season and the brand maturity season) to frame these two stages, respectively. For the brand introduction season (season 0), the retailer sells at a full price from the start of the season. Towards the end of the season, the retailer may offer a markdown discount for a final clearance. For the brand maturity season (season 1), the retailer offers a markdown selling under the high-low price selling, whereas the retailer keeps selling at a single price under other strategies. Unsold products have zero salvage value.

At the starting time of our model in season, the retailer has I products in stock. At this time, the retailer must determine whether to start markdown selling to inform their pricing strategy to consumers, i.e., setting and announcing the fixed markdown discount so that strategic consumers can be well informed. For example, the seller can use price-off promotion by using a number of signs displayed within the store to signal specific prices or markdowns (e.g., "Everything at € 4.99", or "Price 20% off"). At the start of season 1, the retailer needs to decide about the order quantity for season 1. We remark that the selling price is assumed to be exogenous and the start-up inventory I of season 0 is relatively small and it can be sold out without offering any discount. However, the markdown discount offered at season 0 gives a signal so that all the strategic consumers are aware of a potential clearance buying opportunity during each season. As will be discussed in Section 7.3, we extend our discussion when the selling price is endogenous.

We remark that we assume the initial inventory I in the brand introduction period can be sold out at the full price because considering different settings for demands at different stages can better capture the characteristics of new product introduction. Supply and demand mismatch is always a critical issue, mainly caused by inaccurate forecasting and limited production capability (Hendricks and Singhal, 2014). In particular, insufficient supply as one type of supply-demand mismatch is very significant at the new brand/product introduction stage (Ho et al., 2002; Kumar and Swaminathan, 2003). To deal with this problem, "rejecting" part of consumers is an optimal way and has been widely used in the sales of certain types of products, which includes consumer electronics products and fashion products (Shen et al., 2011). Deliberately short supply (underordering) is optimal because it substantially reduces the failure risk of launching a new product and can benefit from causing a buying frenzy (Arifoğlu et al., 2020). Moreover, since forecasting the demand for new products remains challenging, underordering is an effective way to hedge against the risk of demand forecasting at the new product/brand introduction stage.

To simplify the model formulation and inspired by extant literature (Li and Yu, 2014; Hu et al., 2016), we consider a variation of the two-period model and assume that the sequence of the timeline starts after myopic demand has been realized (i.e., at the time to make a markdown sale decision) in season 0. Such a redefinition is due to the fact that the markdown selling period is relatively short and most of the strategic consumers tend to wait and do not make immediate purchasing decisions for a new product/brand by observing only the full/list price. Therefore, strategic demand will be realized after the realization of myopic demand since strategic consumers tend to wait. This is reasonable because consumers who are eagerly waiting for a sale will consider to buy until the markdown sale does not seem to appear. We remark that redefining the start of sequences is common (e.g., Li and Yu, 2014; Hu et al., 2016). As will be discussed in Appendix B, we extend our discussion under a full two-period setting.

Depending on how to sell to strategic consumers, retailers have three selling strategies: fixed pricing, strategic high pricing and high-low pricing. For fixed pricing, the retailer makes a stationary pricing decision among all the selling seasons, that is $p = p_0$. Since there is no potential buying opportunity at discount, existing strategic and myopic consumers behave the same way, whereas new strategic consumers may never buy (or always wait markdown sale until stocking out). Therefore, for a fixed pricing strategy, the actual market size consists of all myopic consumers N_m and existing strategic consumers βN_s.

Strategic high pricing is a selling strategy in which all strategic consumers are induced to buy at a high (full) price through the offered discount in the production/brand introduction stage (season 0). Under this strategy, the retailer must strategically decide the markdown discount $1-\alpha$ in season 0 given rational expectations on consumer surplus, and determine the corresponding order quantity at the start of season 1. Moreover, different from fixed pricing, which has a stationary selling price, the selling prices of each season under strategic high pricing may be different. Comparing with high-low pricing, strategic high pricing usually offers a small discount to induce strategic consumers to buy at full price rather than attract "low-value" consumers to buy at clearance sales. Although price discount in sales can change dynamically across the selling season, many big retailers such as ALDI, Albert Heijn, and Carrefour have used the fixed markdown discount policy widely. To ensure that the problem can be easily analysed, we assume that the offered discounts are fixed and identical across the selling seasons, namely $\alpha{:=}\alpha_0 = \alpha_1$. Retailer's decisions are summarized in Fig. 1.

In the following sections, we derive ordering decision, offered discount, and associated profit under three pricing strategies, including fixed pricing, strategic high pricing, and high-low pricing. Moreover, we identify the optimal condition for each strategy.

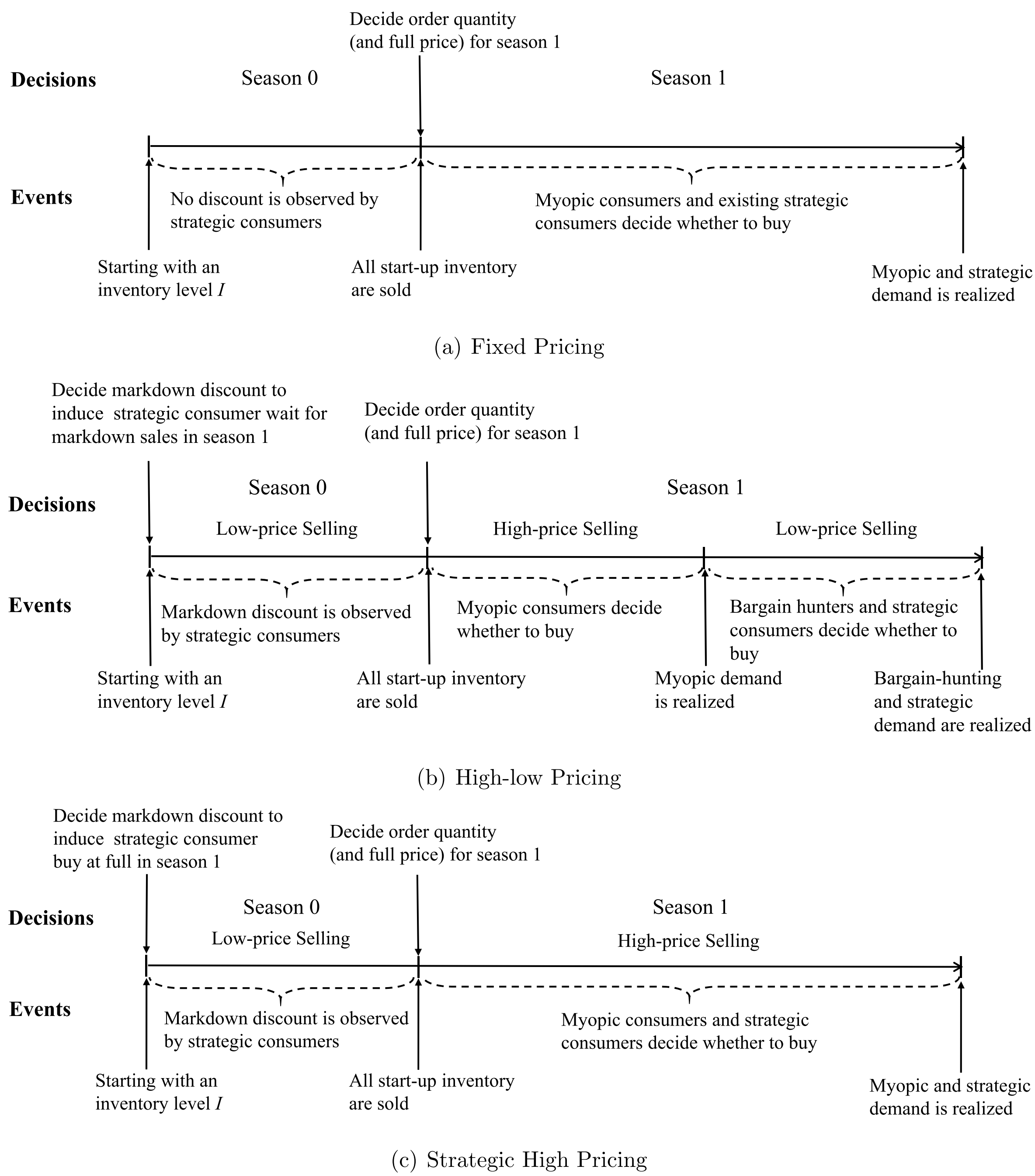


Fig. 1. Timeline of decisions and events.

4. Fixed pricing

We use fixed pricing strategy as a benchmark. Starting with an inventory level I, the retailer keeps selling at the same price, namely $p = p_0$. The only decision that needs to be made is the order quantity for season 1. Therefore, since all start-up inventory I can be sold at p, the profit of season 0 is $\Pi_0 = (p - c)I$. In season 1, consumer valuations have been realized. A consumer buys a product if and only if net utility (consumer surplus) is non-negative, i.e., $v_i - p \geq 0$. The fraction of consumers who make purchases is $E(v_i \geq p) = \overline{F}_v(p)$. Since only existing strategic consumers choose to buy under the fixed pricing strategy, the demand of season 1 is

$$D = D_m + D_s = \sum_{i=1}^{N_m+\beta N_s} E(1(v_i \geq p)) = (N_m + \beta N_s)\overline{F}_v(p),$$

where strategic demand D_s follows a normal distribution with a mean $\beta\mu_s\overline{F}_v(p)$ and a variance $\beta^2\sigma_s^2\overline{F}_v^2(p)$. The retailer's profit for season 1 and its expectation are

$$\begin{aligned}\pi_1(Q) &= (p-c)N_m\overline{F}_v(p) + p(Q \wedge \beta N_s\overline{F}_v(p)) - cQ,\\ \Pi_1(Q) &= (p-c)(Q + N_m\overline{F}_v(p)) - p\beta\overline{F}_v(p)\int_0^{\frac{Q}{\beta\overline{F}_v(p)}} F(x)dx.\end{aligned}$$

Deciding on the optimal order quality for strategic demand is a classic newsvendor problem with a normally distributed strategic market size. Following the standard solution method (e.g. Silver et al., 1998), the optimal order quantity for strategic demand and the profit of season 1 are

$$\begin{aligned}Q_{\text{Fixed}} &= \beta\mu_s\overline{F}_v(p) + \beta k\sigma_s\overline{F}_v(p),\\ \Pi_1(Q_{\text{Fixed}}) &= \underbrace{(p-c)N_m\overline{F}_v(p)}_{\Pi_m} + \underbrace{\beta((p-c)\mu_s\overline{F}_v(p) - p\sigma_s\varphi(k)\overline{F}_v(p))}_{\beta\Pi_s},\end{aligned}$$

where $k = \Phi^{-1}(\frac{p-c}{p})$ and $\Phi(\cdot)$ and $\varphi(\cdot)$ are CDF and PDF of the standard normal distribution, respectively. Π_s and Π_m are the maximum profit from selling to all strategic consumers and myopic consumers at full price p, respectively. Furthermore, the maximal total expected profit is

$$\Pi_{\text{Fixed}} = \underbrace{(p-c)I}_{\Pi_0} + \underbrace{(p-c)N_m\overline{F}_v(p)}_{\Pi_m} + \underbrace{\beta((p-c)\mu_s\overline{F}_v(p) - p\sigma_s\varphi(k)\overline{F}_v(p))}_{\beta\Pi_s}. \tag{5}$$

5. Strategic high pricing

Since new strategic consumers are unaware of the selling strategy, they never buy during season 1 under the fixed pricing strategy. To induce all strategic consumers to make purchases in the regular selling season (season 1), the retailer must offer a discounted price $(1 - \alpha)p_0$ in season 0, such that the expected utility from buying at full price is no less than that from buying at the discounted price $U_s^H(p) \geq U_s^L(p, \alpha)$ or $\alpha \geq \widehat{\alpha}$, where $\widehat{\alpha}$ satisfies equation (4). As a result, the demand during season 1 is $D = (N_m + N_s)\overline{F}_v(p)$, which has a mean $(N_m + \mu_s)\overline{F}_v(p)$ and a variance $\sigma_s^2\overline{F}_v^2(p)$. Then, the retailer's total profit and its expectation are

$$\begin{aligned}\pi_{\text{Strategic}}(Q,\alpha) &= (\alpha p_0 - c)I + p(Q \wedge N_s\overline{F}_v(p)) - cQ + (p-c)N_m\overline{F}_v(p),\\ \Pi_{\text{Strategic}}(Q,\alpha) &= (\alpha p_0 - c)I + (p-c)(Q + N_m\overline{F}_v(p)) - p\overline{F}_v(p)\int_0^{Q/\overline{F}_v(p)} F(x)dx.\end{aligned}$$

To derive optimal decisions, we first optimize α with a fixed p, and then derive the order quantity Q. Since expected total profit is increasing in $\alpha \in [\widehat{\alpha}, \overline{\alpha}]$, the optimal α takes value on its upper bound, that is, $\alpha^* = \overline{\alpha}$. Deriving Q is a classic newsvendor problem. Using standard statistics, the optimal order quantity for strategic demand and the corresponding profit are given by

$$\begin{aligned}Q_{\text{Strategic}} &= \mu_s\overline{F}_v(p) + k\sigma_s\overline{F}_v(p),\\ \Pi_{\text{Strategic}} &= \underbrace{(p_0-c)I}_{\Pi_0} - \underbrace{(1-\overline{\alpha})p_0I}_{C_s(\overline{\alpha})} + \underbrace{(p-c)N_m\overline{F}_v(p)}_{\Pi_m}\\ &\quad + \underbrace{(p-c)\mu_s\overline{F}_v(p) - p\varphi(k)\sigma_s\overline{F}_v(p)}_{\Pi_s},\end{aligned} \tag{6}$$

where $C_s(\overline{\alpha})$ is a cost (profit loss) paid to induce all strategic consumers to make purchases at the full price by offering a $1 - \overline{\alpha}$ discount. By choosing fixed pricing as a benchmark, that is, $p_0 = p$, the profit difference between strategic high pricing and fixed pricing is

$$\Delta\Pi^{\text{SF}} = \Pi_{\text{Strategic}} - \Pi_{\text{Fixed}} = (1-\beta)\Pi_s - C_s(\overline{\alpha}).$$

Note that the first term $(1 - \beta)\Pi_s$ represents the increased profit from selling to extra strategic consumers because a potential discount enlarges the strategic market size. The second term $-C_s(\overline{\alpha})$ is the profit loss (signal cost) from offered discount in season 0.

Whether strategic high pricing is best depends on the trade-off between the added profit from enlarged strategic demand (selling to new strategic consumers) $(1 - \beta)\Pi_s$ and the added cost $C_s(\overline{\alpha})$. This is formalized as follow:

Proposition 1. *(Strategic high pricing vs. Fixed pricing) Fixed pricing dominates strategic high pricing if all strategic consumers are existing consumers, that is, $\beta = 1$. For $\beta \in [0, 1)$, strategic high pricing is best only if the average strategic market size μ_s is bigger than a threshold, that is, $\mu_s \geq \mu_s^{\text{SF}}$, where*

$$\mu_s^{\text{SF}} = \frac{pI(1-\overline{\alpha}) + (1-\beta)p\varphi(k)\sigma_s\overline{F}_v(p)}{(1-\beta)(p-c)\overline{F}_v(p)}.$$

Proof. *See Appendix.*

Proposition 1 shows that whether strategic high pricing is an appropriate approach depends on the strategic market size. This can be explained by the fact that, for a relatively big strategic market size, the added profit from selling to new strategic consumers outweighs the profit loss from offered discount and safety stock increments. Note that, since only existing strategic consumers make purchases under the fixed pricing, the proportion of existing strategic consumers also plays a vital role in determining if strategic high pricing is the best approach if the average market size of strategic consumers is fixed or relatively stable.

6. High-low pricing

The retailer must decide the markdown discount in the introduction stage (season 0) such that all strategic consumers can be induced to wait until the clearance sales in regular-selling stage (season 1). The optimal discount is the smallest value that makes strategic consumers wait, that is, $U_s^L(p, \widehat{\alpha}) = U_s^H(p)$. Then, the retailer faces a newsvendor problem again. The demand of season 1 is $D = N_m\overline{F}_v(p) + N_s\overline{F}_v(\alpha p) + N_b\overline{F}_b(\alpha p)$, which has a mean $(\mu_s + N_m)\overline{F}_v(\alpha p) + N_b\overline{F}_b(\alpha p)$ and a variance $\sigma_s^2\overline{F}_v^2(\alpha p)$. The retailer's total profit and expectation at optimal markdown discount $1 - \widehat{\alpha}$ are

$$\begin{aligned}\pi_{\text{High-Low}}(Q,\widehat{\alpha}) &= (\widehat{\alpha}p_0 - c)I + (p-c)N_m\overline{F}_v(p) + \widehat{\alpha}p(Q \wedge N_s\overline{F}_v(\widehat{\alpha}p))\\ &\quad + (\widehat{\alpha}p - c)N_b\overline{F}_b(\widehat{\alpha}p) - cQ,\\ \Pi_{\text{High-Low}}(Q,\widehat{\alpha}) &= (\widehat{\alpha}p_0 - c)I + (p-c)N_m\overline{F}_v(p) + (\widehat{\alpha}p - c)Q + (\widehat{\alpha}p - c)N_b\overline{F}_b(\widehat{\alpha}p)\\ &\quad - \widehat{\alpha}p\overline{F}_v(\widehat{\alpha}p)\int_0^{\frac{Q}{\overline{F}_v(\widehat{\alpha}p)}} F(x)dx.\end{aligned}$$

Using standard statistics, the optimal order quantity $Q_{\text{High-Low}}$ is given by

$$Q_{\text{High-Low}} = \overline{F}_v(\widehat{\alpha}p)F^{-1}\left(\frac{\widehat{\alpha}p - c}{\widehat{\alpha}p}\right) = \mu_s\overline{F}_v(\widehat{\alpha}p) + k(\widehat{\alpha})\sigma_s\overline{F}_v(\widehat{\alpha}p),$$

and the corresponding maximum expected profit is

$$\begin{aligned}\Pi_{\text{High-Low}} \;=\; & \underbrace{(p_0 - c)I}_{\Pi_0} - \underbrace{(1-\widehat{\alpha})p_0I}_{C_s(\widehat{\alpha})} + \underbrace{(p-c)N_m\overline{F}_v(p)}_{\Pi_m} + \underbrace{(\widehat{\alpha}p - c)N_b\overline{F}_b(\widehat{\alpha}p)}_{\Pi_b(\widehat{\alpha})} \\ & + \underbrace{(\widehat{\alpha}p - c)\mu_s\overline{F}_v(\widehat{\alpha}p) - \widehat{\alpha}p\varphi(k(\widehat{\alpha}))\sigma_s\overline{F}_v(\widehat{\alpha}p)}_{\Pi_s(\widehat{\alpha})},\end{aligned} \tag{7}$$

where $k(\widehat{\alpha}) = \Phi^{-1}(\frac{\widehat{\alpha}p - c}{\widehat{\alpha}p})$ is increasing in $\widehat{\alpha}$, and $\Pi_b(\widehat{\alpha})$ is the profit from selling to bargain hunters at price $\widehat{\alpha}p$.

The maximum profit difference between high-low pricing and fixed pricing is given by

$$\Delta\Pi^{\text{HF}} = \Pi_{\text{High-Low}} - \Pi_{\text{Fixed}} = \Pi_s(\widehat{\alpha}) + \Pi_b(\widehat{\alpha}) - \beta\Pi_s - C_s(\widehat{\alpha}) \tag{8}$$

$$\begin{aligned} = \; & -(1-\widehat{\alpha})p\mu_s\overline{F}_v(p) + (1-\beta)(p-c)\mu_s\overline{F}_v(p) - (1-\beta)\varphi(k)p\sigma_s\overline{F}_v(p) \\ & +(\widehat{\alpha}p - c)N_b\overline{F}_b(\widehat{\alpha}p) - (1-\widehat{\alpha})p_0I + (\widehat{\alpha}p - c)\mu_s(\overline{F}_v(\widehat{\alpha}p) - \overline{F}_v(p)) \\ & -\widehat{\alpha}p\varphi(k(\widehat{\alpha}))\sigma_s(\overline{F}_v(\widehat{\alpha}p) - \overline{F}_v(p)) + (\varphi(k) - \widehat{\alpha}\varphi(k(\widehat{\alpha})))p\sigma_s\overline{F}_v(p)\end{aligned} \tag{9}$$

$$= \mu_sA(\widehat{\alpha}) - B(\widehat{\alpha}),$$

where $A(\widehat{\alpha}) = (\widehat{\alpha}p - c)\overline{F}_v(\widehat{\alpha}p) - (p-c)\beta\overline{F}_v(p)$ and $B(\widehat{\alpha}) = p_0I(1-\widehat{\alpha}) + (\widehat{\alpha}p - c)N_b\overline{F}_b(\widehat{\alpha}p) - \widehat{\alpha}p\varphi(k(\widehat{\alpha}))\sigma_s\overline{F}_v(\widehat{\alpha}p) + p\varphi(k)\sigma_s\overline{F}_v(p)\beta$. Note that the eight terms in equation (9) can be clearly explained. $-(1-\widehat{\alpha})p\mu_s\overline{F}_v(p)$ represents the profit loss from offering markdown discounts to strategic consumers. The second and the third terms, that is, $(1-\beta)(p-c)\mu_s\overline{F}_v(p)$ and $-(1-\beta)\varphi(k)p\sigma_s\overline{F}_v(p)$, are the added profit and the cost of safety stock increments from selling to new strategic consumers who are unwilling to buy under the fixed pricing strategy, respectively. The fourth term $(\widehat{\alpha}p - c)N_b\overline{F}_b(\widehat{\alpha}p)$ is the added profit from selling to bargain hunters. The fifth term $-(1-\widehat{\alpha})p_0I$ is the cost for inducing all strategic consumers to wait until markdown selling starts. The sixth and the seventh terms, that is, $(\widehat{\alpha}p - c)\mu_s(\overline{F}_v(\widehat{\alpha}p) - \overline{F}_v(p))$ and $-\widehat{\alpha}p\varphi(k(\widehat{\alpha}))\sigma_s(\overline{F}_v(\widehat{\alpha}p) - \overline{F}_v(p))$, are the added profit and the safety stock increments from increased strategic market size by the offered markdown discounts, respectively. The final term $(\varphi(k) - \widehat{\alpha}\varphi(k(\widehat{\alpha})))p\sigma_s\overline{F}_v(p)$ is the safety stock reduction on strategic demand from the offered markdown discount.

Equation (8) shows that whether high-low pricing is best relies on the tradeoff between the added profit from high-low pricing and the additional cost for inducing all strategic consumers to wait. The proportion of existing strategic consumer also plays an important role that determines if the added profit from high-low pricing outweighs the added cost for inducing consumers. Furthermore, profit difference also depends heavily on the strategic market size μ_s, and on whether the profit difference is increasing in μ_s, that is, the sign of $A(\widehat{\alpha})$. We formalize the result as follow:

Proposition 2. *(High-low pricing vs. Fixed pricing)*

For any given $\beta \in [0, 1]$, there exist a critical markdown discounted rate $\alpha^{\text{HF}}(\beta) \in [\frac{c}{p}, \overline{\alpha}]$ and a critical average strategic market size $\mu_s^{\text{HF}}(\widehat{\alpha})$ such that $\Delta\Pi^{\text{HF}}(\mu_s^{\text{HF}}(\widehat{\alpha})) = 0$ and $A(\alpha^{\text{HF}}(\beta)) = 0$, respectively.

(a) *When $\widehat{\alpha} \le \alpha^{\text{HF}}(\beta)$, i.e., $A(\widehat{\alpha}) \le 0$, $\Delta\Pi^{\text{HF}}(\beta)$ is decreasing in the average strategic market size μ_s. If $\mu_s^{\text{HF}}(\widehat{\alpha}) \ge 0$ and $\mu_s \le \mu_s^{\text{HF}}(\widehat{\alpha})$, then high-low pricing is best; otherwise, fixed pricing is best;*

(b) *When $\widehat{\alpha} \ge \alpha^{\text{HF}}(\beta)$, i.e., $A(\widehat{\alpha}) \ge 0$, $\Delta\Pi^{\text{HF}}(\beta)$ is increasing in the average strategic market size μ_s. If $\mu_s^{\text{HF}}(\widehat{\alpha}) \ge 0$ and $\mu_s \le \mu_s^{\text{HF}}(\widehat{\alpha})$, then fixed pricing is best; otherwise, high-low pricing is best,*

where $\mu_s^{\text{HF}}(\widehat{\alpha}) = \frac{B(\widehat{\alpha})}{A(\widehat{\alpha})}$ and $\alpha^{\text{HF}}(\beta)$ satisfies $(p-c)\beta\overline{F}_v(p) = (\alpha^{\text{HF}}(\beta)p - c)\overline{F}_v(\alpha^{\text{HF}}(\beta)p)$.

Proof. *See Appendix.*

Fig. 2 provides a graphical illustration of Proposition 2. Intuitively, high-low pricing is appropriate only if the offered discount is relatively small, whereas the critical discounted rate depends heavily on the average strategic market size. When high-low pricing has more benefits than fixed pricing from strategic consumers, that is, $\widehat{\alpha} \ge \alpha^{\text{HF}}$, high-low pricing could be optimal if strategic consumers have a relatively large market size, as illustrated in Fig. 2(a). Note that, as illustrated in Fig. 2 (b), high-low pricing is always suitable for a relatively low offered discount. However, when markdown sales for strategic consumers hurt the retailer, that is, $\widehat{\alpha} \le \alpha^{\text{HF}}$, then high-low pricing is appropriate only if strategic consumers have a relatively small market size.

Having analysed high-low pricing vs. fixed pricing, we next compare the profits between high-low pricing and strategic high pricing. The profit difference between two strategies is given by

$$\begin{aligned}\Delta\Pi^{\text{HS}} \;=\; & \Pi_{\text{High-Low}} - \Pi_{\text{Strategic}} = \Pi_b(\widehat{\alpha}) - (\Pi_s - \Pi_s(\widehat{\alpha})) + C_s(\overline{\alpha}) - C_s(\widehat{\alpha}) \\ =\; & -(1-\widehat{\alpha})p\mu_s\overline{F}_v(p) + (\varphi(k) - \widehat{\alpha}\varphi(k(\widehat{\alpha})))p\sigma_s\overline{F}_v(p) + (\widehat{\alpha}p - c)\mu_s(\overline{F}_v(\widehat{\alpha}p) - \overline{F}_v(p)) \\ & -\widehat{\alpha}p\varphi(k(\widehat{\alpha}))\sigma_s(\overline{F}_v(\alpha p) - \overline{F}_v(p)) - (\overline{\alpha} - \widehat{\alpha})p_0I + (\widehat{\alpha}p - c)N_b\overline{F}_b(\widehat{\alpha}p) \\ =\; & \mu_s\widehat{A}(\widehat{\alpha}) - \widehat{B}(\widehat{\alpha}),\end{aligned} \tag{10}$$

where $\widehat{A}(\widehat{\alpha}) = -(p-c)\overline{F}_v(p) + (\widehat{\alpha}p - c)\overline{F}_v(\widehat{\alpha}p)$ and $\widehat{B}(\widehat{\alpha}) = (\overline{\alpha} - \widehat{\alpha})p_0I + (\widehat{\alpha}p - c)N_b\overline{F}_b(\widehat{\alpha}p) - \widehat{\alpha}p\varphi(k(\widehat{\alpha}))\sigma_s\overline{F}_v(\widehat{\alpha}p) + p\varphi(k)\sigma_s\overline{F}_v(p)$. Note that the first term in equation (10) represents the profit loss from offering a markdown discount. The second term $(\varphi(k) - \widehat{\alpha}\varphi(k(\widehat{\alpha})))p\sigma_s\overline{F}_v(p)$ is safety stock reduction for strategic demand. The third and the fourth terms are the added profit and the safety stock increments from increased strategic market size by offered markdown discounts, respectively. The fifth term $-(\overline{\alpha} - \widehat{\alpha})p_0I$ is the cost for inducing all strategic consumers to wait until markdown selling starts. The final term $(\widehat{\alpha}p - c)N_b\overline{F}_b(\widehat{\alpha}p)$ is the added profit from selling to bargain hunters.

It is clear that whether strategic high pricing is best depends strongly on the strategic market size μ_s and if the profit difference is increasing in μ_s, i.e., the sign of $\widehat{A}(\widehat{\alpha})$. We formalize this result as follow:

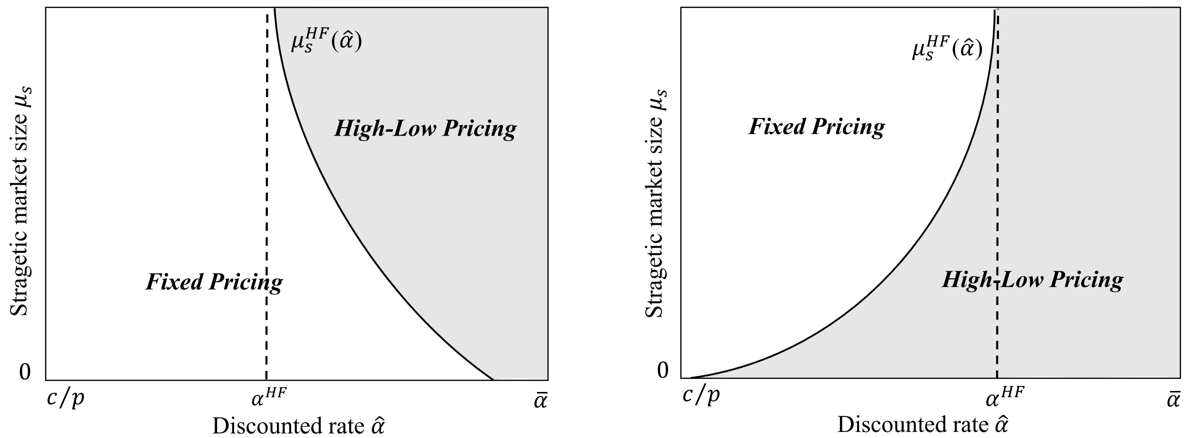
Proposition 3. *(High-low pricing vs. Strategic high pricing)*

There exists a critical markdown discounted rate $\alpha^{\text{HS}} \in [\frac{c}{p}, \overline{\alpha}]$ such that $\widehat{A}(\alpha^{\text{HS}}) = 0$.

(a) *When $\widehat{\alpha} \le \alpha^{\text{HS}}$, that is, $\widehat{A}(\widehat{\alpha}) \le 0$, $\Delta\Pi^{\text{HS}}$ is decreasing in the average strategic market size μ_s. If $0 \le \mu_s \le \mu_s^{\text{HS}}(\widehat{\alpha})$, then high-low pricing is best; otherwise, strategic high pricing is best;*

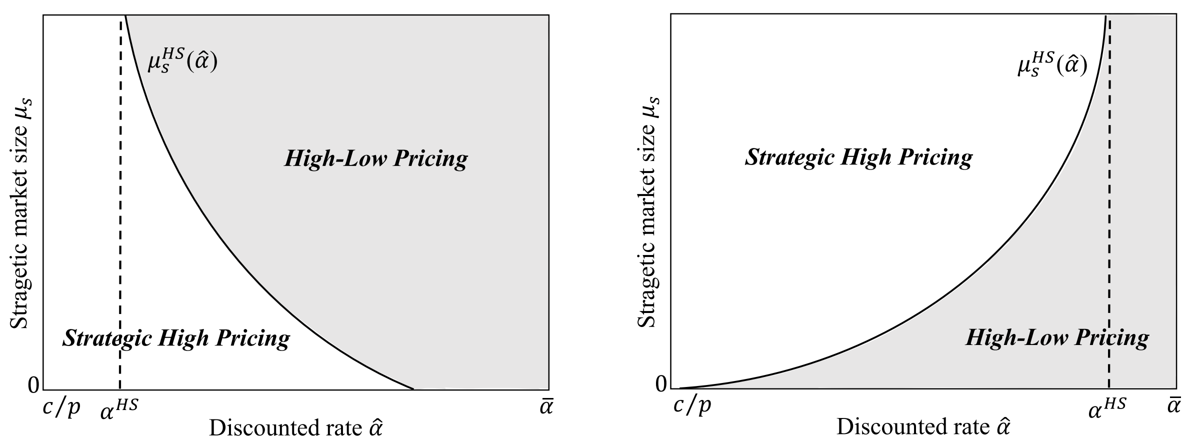
(b) *When $\widehat{\alpha} \ge \alpha^{\text{HS}}$, that is, $\widehat{A}(\widehat{\alpha}) \ge 0$, $\Delta\Pi^{\text{HS}}$ is increasing in the average strategic market size μ_s. If $0 \le \mu_s \le \mu_s^{\text{HS}}(\widehat{\alpha})$, then strategic high pricing is best; otherwise, high-low pricing is best,*

Where $\mu_s^{\text{HS}}(\widehat{\alpha}) = \frac{\widehat{B}(\widehat{\alpha})}{\widehat{A}(\widehat{\alpha})}$ and α^{HS} satisfies $(p-c)\overline{F}_v(p) = (\alpha^{\text{HS}}p - c)\overline{F}_v(\alpha^{\text{HS}}p)$.



(a) (b)

Fig. 2. Optimal selling strategy: High-low pricing vs. fixed pricing.

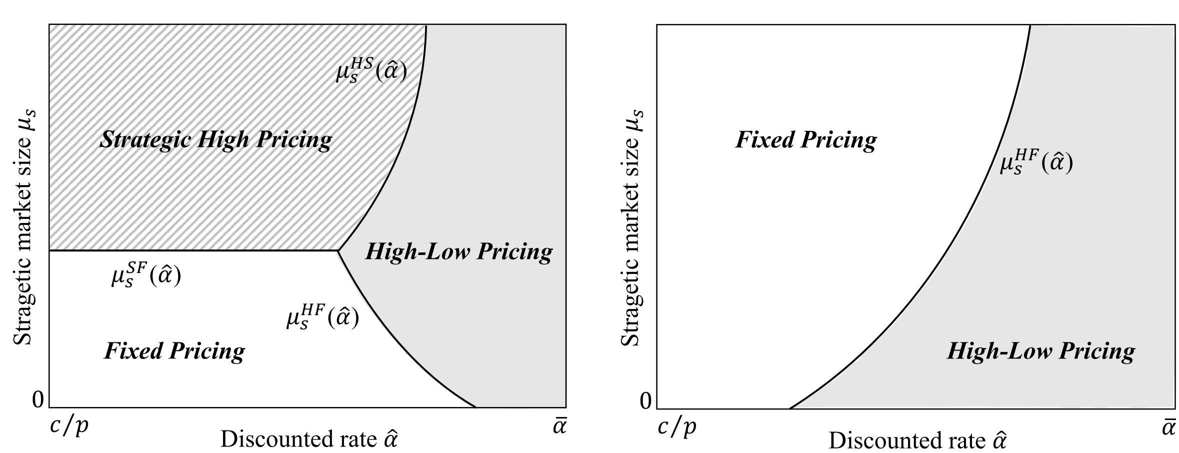


(a) (b)

Fig. 3. Optimal selling strategy: High-low pricing vs. Strategic high pricing.

Proof. *We omit proof here since it is analogue to that of* Proposition 2.

Fig. 3 provides a graphical illustration of Proposition 3. Proposition 3 implies that whether high-low pricing is best depends on both the markdown discount $1 - \widehat{\alpha}$ and the market size of strategic consumers. Intuitively, high-low pricing is best only if the offered discount is relatively small, whereas the critical discounted rate depends strongly on the average strategic market size. When high-low pricing has a higher profit than strategic high pricing due to selling to strategic consumers,



(a) $\beta \in [0, 1)$ (b) $\beta = 1$

Fig. 4. Optimal selling strategy: High-low pricing vs. Strategic high pricing vs. Fixed pricing.

that is, $\hat{\alpha} \geq \alpha^{\text{HS}}$, then further increasing the strategic market size will make high-low pricing to be more profitable and always the best, as illustrated in Fig. 3(a). In some cases, high-low pricing is best regardless of the strategic market size, as shown in Fig. 3(b). When markdown selling to all strategic consumers impairs the retailer, that is, $\hat{\alpha} \leq \alpha^{\text{HS}}$, then high-low pricing is best only if strategic consumers have a relatively small market size. Without fixed pricing, all strategic consumers either buy at the full price or at a discounted price. The existing consumer proportion of strategic consumers plays no role in determining if strategic high pricing is best.

Combined with Propositions 1-3, we identify settings where either of the three strategies is most suitable. This is depicted in Fig. 4. Note that this figure is again an illustration, and we present numerical examples to confirm its shape in the next section. Fig. 4(a) shows that high-low pricing is optimal only if the strategic market size is relatively big and the offered discount is relatively small. For a relatively low discounted rate, fixed pricing is best for a relatively small strategic market size, whereas strategic high pricing is best otherwise. However, as shown in Fig. 4(b), if all the strategic consumers are aware of the retailer's selling strategy, that is, $\beta = 1$, then strategic high pricing is not optimal.

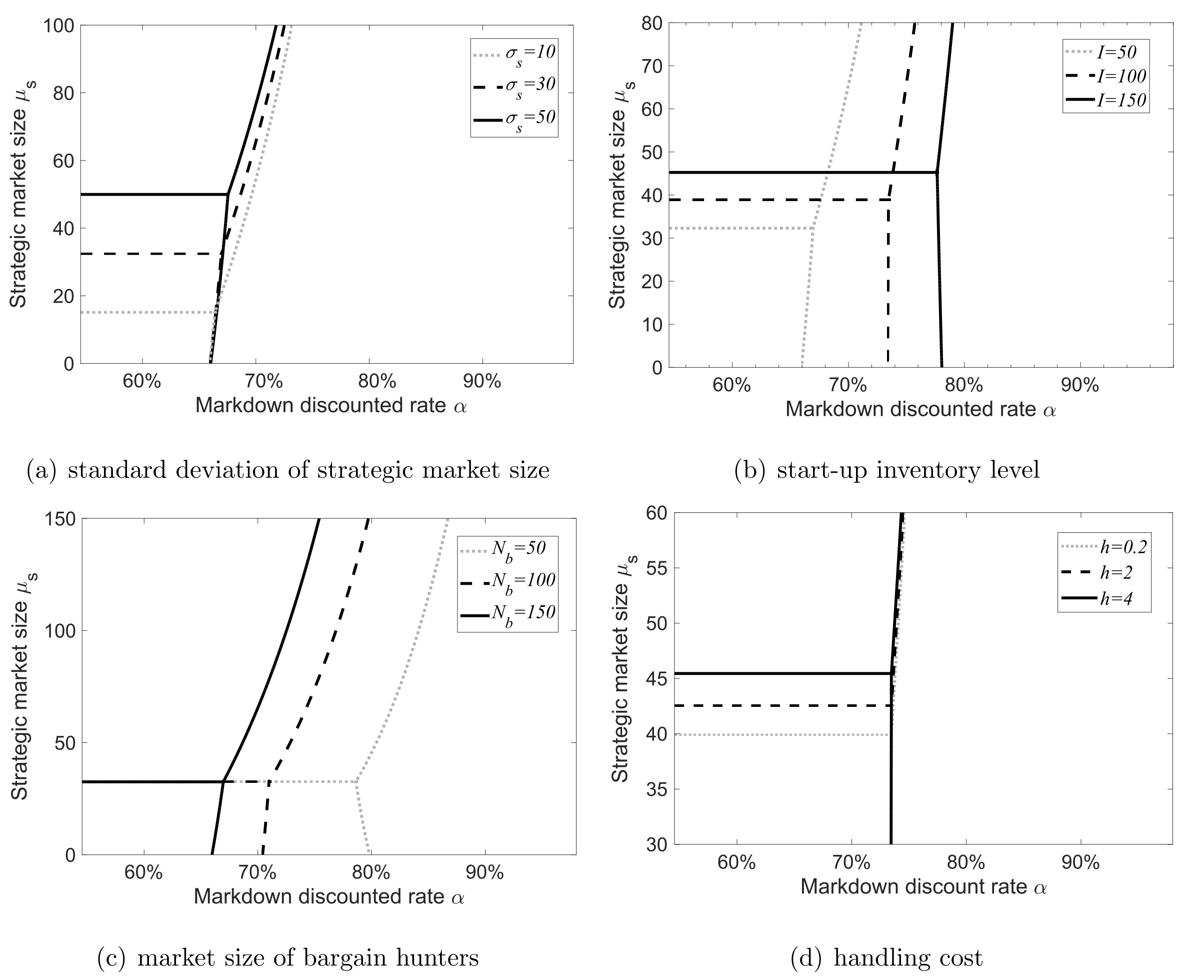
7. Numerical investigation

We have obtained analytical insights into the region (combinations of strategic consumer market size and discounted rates) where a certain type of selling strategy is optimal. Recall that our key contribution is to include fixed pricing, strategic high pricing, and high-low pricing. This section provides further numerical insights on how parameters, including the start-up inventory level, the variance of strategic consumers, the bargain-hunting market size, and the handling cost for unsold products, affect the size of each region. As an extension, we compare the required capacity for the three selling strategies, and further discuss the effect of an endogenous price on the selling strategy, and how consumers benefit from optimal pricing strategies.

7.1. Impact of market conditions

We fix some parameters as follows: $p = p_0 = 11$, $c = 6$, $N_m = 30$, $V \sim N(15, 8^2)$, $V_b \sim N(10.5, 0.5^2)$, $\beta = 0.5$, and $\overline{\alpha} = 98\%$. Other parameters will be varied for the examples considered. We start by varying the standard deviations of strategic market size $\sigma_s \in \{10, 30, 50\}$ and fixing $I = 50$ and $N_b = 150$. Fig. 5(a) shows that significant uncertainty in strategic market size increases the area where fixed pricing and high-low pricing is beneficial. Moreover, strategic high pricing is less likely to be optimal since the safety stock has been increased by a more uncertain strategic market demand. Although increased strategic demand uncertainty also affects fixed pricing, the safety stock increment must only fulfil the strategic demand from existing consumers, which has a smaller amount than strategic high pricing.

Secondly, we vary the start-up inventory $I \in \{50, 100, 150\}$ and fix $\sigma_s = 30$ and $N_b = 150$. Intuitively, it is more likely that fixed pricing becomes optimal as the cost for inducing strategic consumers increases. Fig. 5(b) confirms that the region of fixed pricing is increasing. For high-low pricing, an increased start-up inventory always impairs the retailer which leads the strategy is optimal if the offered discount is relatively small. Moreover, for a given discounted price, keeping strategic high



(a) standard deviation of strategic market size (b) start-up inventory level

(c) market size of bargain hunters (d) handling cost

Fig. 5. Optimal policy with varying parameters.

pricing optimal requires a relatively large strategic market when the inducing cost is increased by a higher start-up inventory level.

Next, we vary the bargain-hunting market size $N_b \in \{50, 100, 150\}$ and fix $\sigma_s = 30$ and $I = 50$. Intuitively, more bargain hunters let markdown selling to become more profitable. Thereby, a big bargain hunter market size increases the size of the area where high-low pricing is beneficial. Note that the critical strategic market size $\mu_s^{SF}(\widehat{\alpha})$ is unchanged by the bargain-hunting market size because bargain hunters buy only during clearance sales.

Finally, we consider the impact of handling costs for unsold products. Due to the ever-increasing environmental requirements, handling unsold products is becoming very costly, especially for eco-unfriendly products. Therefore, saving handling costs for unsold products is an important driver to motivate the retailer to clean up inventory by markdown selling. After incorporating the handling cost per unit which is denoted by h into the model, the maximal expected profits under each selling strategy are updated to

$$\begin{aligned}
\Pi_{\text{Fixed}} &= (p-c)I + (p-c)N_m\overline{F}_v(p) + \beta((p-c)\mu_s\overline{F}_v(p) - (p+h)\sigma_s\varphi(k_h)\overline{F}_v(p)),\\
\Pi_{\text{Strategic}} &= (p_0-c)I - (1-\overline{\alpha})p_0 I + (p-c)N_m\overline{F}_v(p) + (p-c)\mu_s\overline{F}_v(p) - (p+h)\varphi(k_h)\sigma_s\overline{F}_v(p),\\
\Pi_{\text{High-low}} &= (p_0-c)I - (1-\widehat{\alpha})p_0 I + (p-c)N_m\overline{F}_v(p) + (\widehat{\alpha}p-c)N_b\overline{F}_b(\widehat{\alpha}p)\\
&\quad +(\widehat{\alpha}p-c)\mu_s\overline{F}_v(\widehat{\alpha}p) - (\widehat{\alpha}p+h)\varphi(k_h(\widehat{\alpha}))\sigma_s\overline{F}_v(\widehat{\alpha}p),
\end{aligned}$$

where $k_h = \Phi^{-1}(\frac{p-c}{p+h})$ and $k_h(\widehat{\alpha}) = \Phi^{-1}(\frac{\widehat{\alpha}p-c}{\widehat{\alpha}p+h})$.

We vary the handling cost $h \in \{0.5, 2, 4\}$ and fix $\sigma_s = 30$, $I = 100$ and $N_b = 150$. Fig. 5(d) shows that the region of the fixed pricing/the strategic high pricing becomes larger/smaller when h increases. This is because the strategic high pricing has more unsold products. Specifically, compared to the fixed-pricing strategy, the overstock risk under the strategic high pricing strategy is enlarged, which further results in more unsold products. As a result, as the handling cost increases, it is less likely that strategic high pricing becomes optimal. Further, since the handling cost does not affect consumer's expected utility and thereby the markdown discount, the effect of the handling cost on the choice of the high-low pricing strategy is insignificant.

7.2. Comparison of required capacity

In this section, we examine the impact of the different pricing strategies on the required capacity measured by the size of the total order quantity. Based on Sections 4, 5, and 6, the required capacity of the three selling strategies are summarized as follow:

$$\begin{aligned}
Q^{\Sigma}_{\text{Fixed}} &= I + N_m\overline{F}_v(p) + \beta\mu_s\overline{F}_v(p) + \beta k\sigma_s\overline{F}_v(p),\\
Q^{\Sigma}_{\text{Strategic}} &= I + N_m\overline{F}_v(p) + \mu_s\overline{F}_v(p) + k\sigma_s\overline{F}_v(p),\\
Q^{\Sigma}_{\text{High-Low}} &= I + N_m\overline{F}_v(p) + N_b\overline{F}_b(\widehat{\alpha}p) + \mu_s\overline{F}_v(\widehat{\alpha}p) + k(\widehat{\alpha})\sigma_s\overline{F}_v(\widehat{\alpha}p).
\end{aligned}$$

As pointed out by Cachon and Swinney (2009) that bargain hunters usually have a relatively big market size (i.e., they assumed it has infinite numbers), we focus on the case that the safety stock deduction of strategic demand by high-low pricing is far less than the demand increment from selling to bargain-hunters at low prices. In other words, we assume that bargain-hunting demand has a lower bound, i.e., $N_b\overline{F}_b(\widehat{\alpha}p) \geq S(\widehat{\alpha}, \beta)$ holds for any $\beta \in [0, 1]$, where the lower bound $S(\widehat{\alpha}, \beta) = \beta k\sigma_s\overline{F}_v(p) - k(\widehat{\alpha})\sigma_s\overline{F}_v(\widehat{\alpha}p)$ is the safety stock deduction of strategic demand due to the offered markdown discount. Then, we formalize the comparison of the required capacity of these three strategies as follows.

Proposition 4. *The high-low pricing has the highest required capacity, whereas the fixed pricing has the lowest required capacity, i.e.,* $Q^{\Sigma}_{\text{High-Low}} \geq Q^{\Sigma}_{\text{Strategic}} \geq Q^{\Sigma}_{\text{Fixed}}$.

Proof. *See Appendix.*

It is not surprising that the high-low pricing demands the highest capacity because both myopic and strategic demands are enlarged by offering low pricing. In addition, there is an increased demand from selling to the bargain hunters, whereas the fixed pricing has the lowest capacity due to the highest selling price. To gain more insights, we perform the following numerical experiment based on the general parameter settings in Section 7.1. Other parameters are set as follows: $I = 50$, $N_b = 150$, $\sigma_s = 10$ and $\widehat{\alpha} = 70\%$.

As Fig. 6(a) shows, the required capacities under all strategies are increasing with respect to the strategic market size. This is intuitive because increased demand needs capacity enlargement. Compared to the fixed pricing, the high-low pricing demands too much capacity, even more than 200%. However, as Fig. 6(b) shows, excess capacity does not

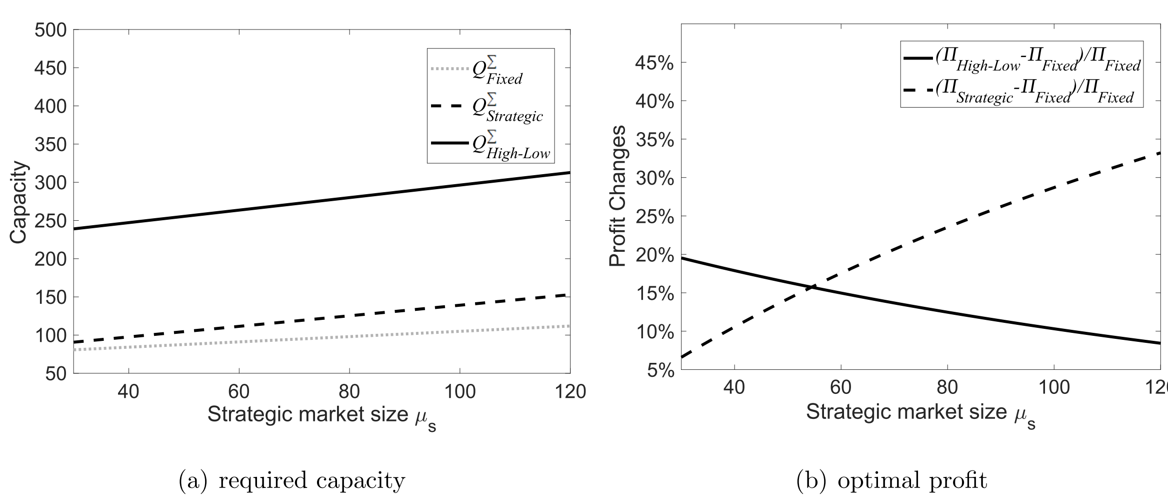


Fig. 6. Comparison of required capacities and optimal profits.

Table 2
Optimal prices and maximal profit with a small strategic market size $\mu_s = 20$.

Cost	High-Low Pricing			Fixed Pricing		Strategic High Pricing	
	Discount(%)	Price in season 1	Profit	Price in each season	Profit	Price in season 1	Profit
c	$1-\hat{\alpha}$	$(p, \hat{\alpha}p)$	$\Pi_{\text{High-Low}}$	$p = p_0$	Π_{Fixed}	p	$\Pi_{\text{Strategic}}$
1.0	49.0%	(13.12, 6.69)	176.13	5.91	**177.61**	5.85	177.39
1.5	45.0%	(13.47, 7.41)	148.08	6.23	**151.76**	6.15	142.53
2.0	42.9%	(13.67, 7.80)	125.27	6.55	**129.41**	6.55	113.68
2.5	39.7%	(14.02, 8.46)	107.06	6.86	**110.03**	6.84	89.67
3.0	38.0%	(14.21, 8.81)	91.48	7.24	**93.26**	7.24	69.72
3.5	35.4%	(14.56, 9.41)	78.57	7.62	**78.83**	7.64	53.15
4.0	34.0%	(14.76, 9.74)	**67.08**	8.00	66.52	8.04	39.46
4.5	32.8%	(14.95, 10.05)	**56.92**	8.44	56.13	8.44	28.19
5.0	31.7%	(15.15, 10.35)	**47.79**	8.94	47.50	8.94	18.94

Table 3
Optimal prices and maximal profit with a big strategic market size $\mu_s = 180$.

Cost	High-Low Pricing			Fixed Pricing		Strategic High Pricing	
	Discount(%)	Price in season 1	Profit	Price in each season	Profit	Price in season 1	Profit
c	$1-\hat{\alpha}$	$(p, \hat{\alpha}p)$	$\Pi_{\text{High-Low}}$	$p = p_0$	Π_{Fixed}	p	$\Pi_{\text{Strategic}}$
1.0	55.3%	(12.67, 5.66)	574.33	5.61	380.34	5.55	**584.18**
1.5	52.4%	(12.86, 6.12)	496.58	5.86	331.64	5.74	**503.58**
2.0	51.8%	(12.91, 6.22)	427.85	6.18	287.69	6.04	**431.63**
2.5	49.2%	(13.11, 6.66)	366.11	6.44	248.05	6.34	**367.13**
3.0	48.6%	(13.15, 6.76)	**310.81**	6.70	212.38	6.64	309.45
3.5	46.3%	(13.35, 7.17)	**262.19**	7.02	180.51	6.93	258.15
4.0	44.2%	(13.55, 7.56)	**218.90**	7.33	152.21	7.23	212.79
4.5	42.2%	(13.74, 7.94)	**180.77**	7.65	127.32	7.53	172.99
5.0	40.3%	(13.94, 8.32)	**147.48**	8.03	105.64	7.83	138.33

bring much more profits. Specifically, profit increase is less than 20%, and is decreasing with the strategic market size. This is because too much capacity is used to fulfill the bargain-hunting demand at a very low profit margin. Further, consistent with Figs. 5 and 6(b) shows that if the strategic market size is relatively large, the strategic high pricing strategy may outperform other strategies in the tradeoff between capacity enlargement and profit increment, e.g., compared fixed pricing, 32.6% increase in capacity leads to 28.7% increase in profits when $\mu_s = 100$.

7.3. Endogeneity of selling price

We extend our study by considering an endogenous price and discuss the effect of price endogeneity on selling strategy by numerically solving the first-order conditions of Π_{Fixed}, $\Pi_{\text{Strategic}}$, and $\Pi_{\text{High-Low}}$ given in equations (5)–(7), respectively. Some parameters are fixed as follows: $N_m = 60$, $\beta = 0.5$, $N_b = 70$, $\sigma_s = 60$, $V \sim N(6, 3^2)$, $V_b \sim N(5, 5.5^2)$, $\overline{\alpha} = 90\%$, $\lambda = 0.01$, and $I = 5$. We let $p_0 = 6$ for both strategic high pricing and high-low pricing and vary the purchasing cost $c \in [1, 5]$ and consider the market size $\mu_s \in \{20, 180\}$ side by side.

From Tables 2 and 3, we observe the same effects for an exogenous price during season 1 in Fig. 4. More specifically, high-low pricing is always appropriate if the offered discount is not very high, that is, less than 49% (34%) for a big (small) strategic market size. Otherwise, whether fixed pricing is best relies on the strategic market size.

However, there are some changes to be aware of for those that relate to price endogeneity. Intuitively, when the cost increases, the optimal selling price in season 1 is seen to always increase. Surprisingly, the high (full) price in season 1 under the high-low pricing is much higher (even more than 100%) than that under other pricing strategies. Moreover, the price gap between high and low prices is also very wide. This can be explained by the fact that high-low pricing is best only if the offered discount is not very high; moreover, to ensure the profitability of high-low pricing, the high (full) price must be increased. Likewise, as the unit cost decreases, high-low pricing strategy may not be the best. These observations are consistent with the real world. For example, high-low pricing is profitable and ubiquitous in fashion retailing. Generally, retailers set a very high list price at season opening and offer a huge discount for clearance sales during the closing period. Moreover, the selling

Table 4
Consumer welfare at the optimal prices.

(a) $\mu_s = 20$

Cost	High-Low		Fixed	Strategic High
	Myopic/ Strategic	Bargain hunting	Myopic/ Strategic	Myopic/ Strategic
1.0	0.01	1.45	**1.24**	1.27
1.5	0.01	1.20	**1.09**	1.13
2.0	0.01	1.07	**0.94**	0.94
2.5	0.00	0.89	**0.81**	0.82
3.0	0.00	0.80	**0.68**	0.68
3.5	0.00	0.66	**0.56**	0.55
4.0	**0.00**	**0.59**	0.45	0.44
4.5	**0.00**	**0.53**	0.35	0.35
5.0	**0.00**	**0.48**	0.26	0.26

(b) $\mu_s = 180$

Cost	High-Low		Fixed	Strategic High
	Myopic/ Strategic	Bargain hunting	Myopic/ Strategic	Myopic/ Strategic
1.0	0.01	1.88	1.40	**1.44**
1.5	0.01	1.68	1.27	**1.33**
2.0	0.01	1.64	1.11	**1.18**
2.5	0.01	1.46	0.99	**1.04**
3.0	**0.01**	**1.43**	0.88	0.91
3.5	**0.01**	**1.28**	0.76	0.79
4.0	**0.01**	**1.15**	0.65	0.68
4.5	**0.00**	**1.03**	0.55	0.58
5.0	**0.00**	**0.92**	0.45	0.50

Note. Consumer welfare under the optimal strategy are highlighted in bold.

price under fixed pricing and strategic high pricing may be even lower than the discounted price of high-low pricing. This is due to the fact that the demand increment offsets the lowerd profit margin. Such observation confirms that "everyday low price" is best for selling low-cost products.

7.4. Consumer welfare

Profit seeking business provides social benefits to consumers and producers. In theory, low price increases consumer surplus, and thereby brings about an improvement in consumer welfare. In this section, we numerically explore to what extent do consumers benefit from different pricing strategies. We measure the impact of pricing strategy on consumer welfare by the amount of consumer surplus at the optimal selling prices. More specifically, the welfare of myopic consumer, strategic consumer and bargain-hunter consumer U_m, U_s^L and U_b are defined by (1)-(3), respectively.

We keep parameters settings presented in Section 7.2. Table 4 gives the consumer welfare across different costs. Note that strategic consumers behave the same as myopic consumers under the strategies of fixed pricing and strategic high pricing. Moreover, under the high-low pricing strategy, the low price is such that buying at high (full) price has the same utility with buying at a low price, i.e., $U_m = U_s^H = U_s^L$. Therefore, for any pricing strategy, myopic and strategic consumers have the same consumer welfare.

The table shows that fixed pricing and strategic high pricing significantly improve the welfare of myopic and strategic consumers. Since the price under the high-low pricing strategy is such that myopic and strategic consumers have no surplus, as the table shows, myopic and strategic consumers has no welfare. However, high-low pricing improves the welfare of bargain-hunters since this consumer type never buys at high price. In other words, from the perspective of consumer welfare, high-low pricing benefits bargain-hunters but hurts myopic and strategic consumers. Moreover, as Table 4(a) shows, for selling high-margin products to myopic and strategic consumers in a market with a relatively small strategic market size, fixed pricing as the optimal strategy may do little harm to consumer welfare (less than 4%) due to price increment.

8. Conclusion

This work studies the optimal pricing strategy of a newsvendor retailer in a market with strategic consumers. Consumers are heterogeneous (strategic, myopic and bargain hunting) and their product valuations are unknown to the retailer. The retailer uses different price discounts to inform consumers about their selling strategy in the product/brand introduction stage. Our study explores the best selling strategy across different product development stages. We develop a newsvendor framework to investigate the overall effects of strategic buying behaviour on pricing strategies and identify conditions where fixed pricing, strategic high pricing, and high-low pricing are appropriate. We analytically compare the profits of three pricing strategies. We show that high-low pricing is best only if the offered discount is relatively small. Fixed pricing is the best approach only if strategic consumers comprise a small population and the offered discount for high-low pricing is relatively big. Otherwise, strategic high-pricing strategy is best. Numerical investigations further confirm the structural result under multiple settings. Our results imply that the needed markdown discount and the market size of existing strategic consumers play crucial roles in pricing strategy selection.

The contribution of this work is twofold. First, most literature (e.g. Cachon and Swinney, 2009; Dong and Wu, 2019) under the dynamic (high-low) pricing strategy examines how to set a markdown price for clearance sales in the presence of strategic consumers. By considering a pre-announced markdown discount, they find that strategic buying behaviour always impairs the retailer's profit, and high-low pricing is desirable because it can benefit from salvaging unsold inventory. Our results confirm that strategic buying behaviour hurts retailers; however, high-low pricing is best only if the offered discount is relatively small. Moreover, although offering a markdown discount may be beneficial from salvaging unsold inventory in the current selling season, it is costly because the retailer forgoes the potential losses from future sales in the following seasons.

Second, although some studies (e.g. Aviv and Pazgal, 2008) show that fixed pricing has only a slight disadvantage in comparison to markdown discount commitment. Nowadays, fixed pricing is becoming more costly because new strategic consumers may choose to wait rather than make purchases right away, and the retailer forgoes the opportunity to salvage inventory. Our results show that fixed pricing is the best approach only if strategic consumers comprise a small population and the offered discount for high-low pricing is relatively big. If strategic market size is huge, then offering a small discount to induce all strategic consumers to buy early, that is, strategic high-pricing strategy, is the best approach. Furthermore, we study how to induce strategic consumers' buying decisions and discuss the profitability of inducing strategic consumers in different ways.

Finally, this work contributes towards a more realistic model of new strategic consumers who are unaware of the retailer's selling strategy. We consider that new strategic consumers always choose to wait. By considering consumer heterogeneity, the market structure and price discount offered for clearance sales play crucial roles in determining the appropriate pricing strategy. If all strategic consumers are existing consumers, then two widely used pricing strategies, namely fixed pricing and high-low pricing, are always the best. However, if some strategic consumers are unaware of the retailer's selling strategy, then besides fixed pricing and high-low pricing, strategic high pricing is another optimal pricing strategy that can induce all strategic consumers to buy at full prices through regular promotion or by offering a small discount.

Numerical investigation for the effect of price endogeneity on the selling strategy shows that the structural results carry over. However, the price gap is wide, and the optimal (full) prices of fixed pricing and strategic high pricing are close to the low price of the high-low pricing. These findings are consistent with the real-world business and have important managerial implications for retailers. Current strategies at fast-fashion retailers are the most compelling examples to support these implications. In fast fashion, it is quite common to observe high-low pricing in many brands (e.g., Ralph Lauren and Levi's). To ensure a relatively huge offered discount, these retailers usually set a very high list price at season opening and later offer a substantial discount for clearance sales. Ghemawat and Nueno (2003) report that 30%–40% of most European retailers' sales are obtained through markdown sales. However, most self-branded fast-fashion retailers, such as Netherland-based HEMA, adopt fixed pricing strategy and sell their products at low prices. To induce consumers not to wait, some retailers have adopted strategies to thwart strategic buying behavior. Zara is one of the compelling examples of (strategic) high pricing strategy. Zara is know for deliberately setting low inventory levels and keeping high prices (offering very small discounts). In average, 85% of products at a Zara store are sold at their full prices (Ferdows et al., 2002; Caro and Gallien, 2012). Miguel Díaz Miranda, a vice president at Zara, explained this strategy as "the culture we are creating with our customers is: you better get it today because you might not find it tomorrow" (Liu and van Ryzin, 2008).

Besides Zara, a group of brands that vary across price induces and encourages consumers to pay full price. These brands include luxury brands (Louis Vuitton, Tiffany, Hermès and Chanel), premium brands (e.g., Everlane, Kent Wang, Apple), valuable brands (e.g., Huawei, Xiaomi). The methods they employ include never markdown and offering a very tiny discount to very few (loyal) consumers, which correspond to fixed price selling and strategic high price selling. EDITD, the leader in retail intelligence, analysed the discounting trends in the US and UK markets (Smith, 2014). The analysis shows that both the luxury market and the value market have a small proportion of discounted products. Specifically, nearly 69% of luxury products and 61% of valuable products did not offer any discount in 2014. For luxury brands, even some of the brands may hold sales, the sales are irregular and are only for a very tiny number of seasonable products. Similar to the luxury market, there is almost no discount in the value market since the profit margin is relatively low. For example, as the world's second-largest smartphone maker, Xiaomi has been known for its cost-effective smartphones and keeps selling its products at the list price.

Our results also have managerial implications from the perspective of production economics. Our results show that although the high-low pricing may have the highest profit, it demands much more production capacity than other strategies. Compared to other strategies, the excess capacity which is used to fulfill the bargain-hunting demand brings very little profit. Therefore, we suggest that the high-low pricing strategy is more suitable when the capacity utilization of manufacturers is relatively low. If manufacturers have a limited capacity, then either the strategic high pricing or the fixed pricing is preferred. However, compared to the fixed pricing, the strategic high pricing yields more unsold products. This indicates that although the strategic-high pricing can lower the requirement for capacity, it is less likely to be profitable if the unsold products are not eco-friendly. Therefore, when handling unsold products is very costly due to the ever-increasing environmental requirements, our recommendation is to use either high-low pricing or fixed pricing. In particular, the fixed pricing is preferred when manufacturers have a very limited capacity.

There are some limitations to our work. First, we restrict analysis to the case that market sizes of myopic and bargain-hunting consumers are deterministic. In fact, market sizes are uncertain. It is worthwhile to extend our model to uncertain market sizes of myopic and bargain-hunting consumers. Second, all consumers are assumed to be independent, and they can accurately predict future price discounts. In practice, consumers may be dependent (i.e. social learning) and diversified (i.e. different discount predictions). Another future research avenue is to extend our analysis by considering dependent consumers and to explore the impact of price-prediction risks. Finally, to strengthen the credibility of our results, it would be valuable to test them in an empirical study. Researchers can adopt the case study method to test if our findings are confirmed in a specific firm. For example, interviews can be used to ask retailers how they decided on the selling strategy and order quantities of new products and how they managed strategic consumer behaviour. Moreover, experimental researchers can design experiments to verify if decision makers show the same behaviour under the conditions specified in our paper.

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Appendix A. Proofs

Proof of Proposition 1. If $\beta = 1$, then $\Delta\Pi^{SF} = -C_s(\overline{\alpha}) < 0$ always holds. For $\beta \in [0, 1)$, differentiating $\Delta\Pi^{SF}$ with respect to μ_s gives $\frac{d\Delta\Pi^{SF}}{d\mu_s} = (1-\beta)(p-c)\overline{F}_v(p)$. Clearly, $\Delta\Pi^{SF}$ is increasing in μ_s and starts from a negative value, i.e., $\Delta\Pi^{SF}|_{\mu_s=0} < 0$. Therefore, there exists a critical μ_s^{SF} such that $\Delta\Pi^{SF}(\mu_s^{SF}) = 0$.

Proof of Proposition 2. Let $r(\widehat{\alpha}) = (\widehat{\alpha}p - c)\overline{F}_v(\widehat{\alpha}p)$. Differentiating $\Delta\Pi^{HF}$ with respect to μ_s gives

$$\frac{d\Delta\Pi^{HF}}{d\mu_s} = r(\widehat{\alpha}) - (p-c)\beta\overline{F}_v(p) = r(\widehat{\alpha}) - \beta r(1),$$

where $\beta \in [0, 1]$, which implies $\Delta\Pi^{HF}$ is a linear function of μ_s. As a result, the sign of $\Delta\Pi^{HF}$ depends on both the signs of $\frac{d\Delta\Pi^{HF}}{d\mu_s}$ and $\Delta\Pi^{HF}|_{\mu_s=0}$. More specifically, if $\Delta\Pi^{HF}|_{\mu_s=0} \geq (\leq)0$ and $\frac{d\Delta\Pi^{HF}}{d\mu_s} \leq (\geq)0$, then there exist a critical $\mu_s^{HF}(\widehat{\alpha})$ such that $\Delta\Pi^{HF}(\mu_s^{HF}) = 0$. Then, $\Delta\Pi^{HF} \geq (\leq)0$ if $\mu_s \leq \mu_s^{HF}$; if $\Delta\Pi^{HF}|_{\mu_s=0} \geq (\leq)0$ and $\frac{d\Delta\Pi^{HF}}{d\mu_s} \geq (\leq)0$, then $\Delta\Pi^{HF} \geq (\leq)0$ always holds. Therefore, to prove this theorem, we have to verify the sign of $\frac{d\Delta\Pi^{HF}}{d\mu_s}$.

Note that $\frac{d\Delta\Pi^{HF}}{d\mu_s}|_{\widehat{\alpha}=\frac{c}{p}} = -(p-c)\beta\overline{F}_v(p) \leq 0$ and $\lim_{\overline{\alpha}\to 1}\frac{d\Delta\Pi^{HF}}{d\mu_s}|_{\widehat{\alpha}=\overline{\alpha}} = (p-c)(1-\beta)\overline{F}_v(p) \geq 0$. If $\frac{d\Delta\Pi^{HF}}{d\mu_s}$ or $r(\widehat{\alpha})$ is quasi-concave in $\widehat{\alpha}$, then there is a unique $\alpha^{HF}(\beta)$ such that $\frac{d\Delta\Pi^{HF}}{d\mu_s}|_{\widehat{\alpha}=\alpha^{HF}(\beta)} = 0$, that is $(\widehat{\alpha}p - c)\overline{F}_v(\widehat{\alpha}p) - (p-c)\beta\overline{F}_v(p) = 0$. To proceed, we only need to prove that $r(\widehat{\alpha})$ is quasi-concave.

Differentiating $r(\widehat{\alpha})$ with respect to $\widehat{\alpha}$ gives

$$\frac{dr(\widehat{\alpha})}{d\widehat{\alpha}} = p(\overline{F}_v(\widehat{\alpha}p) - (\widehat{\alpha}p - c)f(\widehat{\alpha}p)).$$

Note that $\frac{dr(\widehat{\alpha p})}{d\widehat{\alpha}}|_{\widehat{\alpha}=\frac{c}{p}} = p\overline{F}_v(\widehat{\alpha}p) > 0$ and $\frac{dr(\widehat{\alpha p})}{d\widehat{\alpha}}|_{\widehat{\alpha}=\overline{\alpha}} = p(\overline{F}_v(\overline{\alpha}p) - (\overline{\alpha}p - c)f(\overline{\alpha}p))$, where $\lim_{\overline{\alpha}\to 1}\frac{dr(\widehat{\alpha p})}{d\widehat{\alpha}}|_{\widehat{\alpha}=\overline{\alpha}} = -(\widehat{\alpha}p - c)f(\widehat{\alpha}p)). < 0$. Therefore, $\frac{dr(\widehat{\alpha})}{d\widehat{\alpha}} = 0$ has at least one solution. Taking the second derivative with respect to $\widehat{\alpha}$ gives

$$\frac{d^2r(\widehat{\alpha})}{d\widehat{\alpha}^2} = p^2((\alpha p - c)y''(\widehat{\alpha}p) + 2y'(\widehat{\alpha}p))$$

where $y(\widehat{\alpha}p) := \overline{F}_v(\widehat{\alpha}p)$, $y'(\widehat{\alpha}p) = \frac{\mathrm{d}(\overline{F}_v(\widehat{\alpha}p))}{\mathrm{d}(\widehat{\alpha}p)}$ and $y''(\widehat{\alpha}p) = \frac{\mathrm{d}^2(\overline{F}_v(\widehat{\alpha}p))}{\mathrm{d}(\widehat{\alpha}p)^2}$. Since $\overline{F}_v(\widehat{\alpha}p)$ has an IPE, i.e., $y''(\widehat{\alpha}p) \le (\frac{\widehat{\alpha}py'(\widehat{\alpha}p)}{y(\widehat{\alpha}p)} - 1)\frac{y'(\widehat{\alpha}p)}{\widehat{\alpha}p}$, we then have

$$\begin{aligned}\frac{\mathrm{d}^2 r(\widehat{\alpha})}{\mathrm{d}\widehat{\alpha}^2} &\le p^2\left((\widehat{\alpha}p - c)\left(\frac{\widehat{\alpha}py'(\widehat{\alpha}p)}{y(\widehat{\alpha}p)} - 1\right)\frac{y'(\widehat{\alpha}p)}{\widehat{\alpha}p}\right) + 2y'(\widehat{\alpha}p),\\ &= p^2\left(\frac{(\widehat{\alpha}p - c)y'^2(\widehat{\alpha}p)}{y(\widehat{\alpha}p)} + y'(\widehat{\alpha}p) + \frac{cy'(\widehat{\alpha}p)}{\widehat{\alpha}p}\right).\end{aligned}$$

Further, we have

$$\frac{\mathrm{d}^2 r(\widehat{\alpha})}{\mathrm{d}\widehat{\alpha}^2}\Big|_{\frac{\mathrm{d}r(\widehat{\alpha})}{\mathrm{d}\widehat{\alpha}}=0} = \frac{y'(\widehat{\alpha}p)}{\widehat{\alpha}p}[-\widehat{\alpha}p + \widehat{\alpha}p + c] < 0.$$

Therefore, $r(\widehat{\alpha})$ is quasi-concave in $\widehat{\alpha}$.

Proof of Proposition 4. By letting $\Delta Q^{\Sigma}_{HF} := Q^{\Sigma}_{\text{High-Low}} - Q^{\Sigma}_{\text{Fixed}} = \mu_s(\overline{F}_v(\widehat{\alpha}p) - \beta\overline{F}_v(p)) + k(\widehat{\alpha})\sigma_s\overline{F}_v(\widehat{\alpha}p) - \beta k\sigma_s\overline{F}_v(p) + N_b\overline{F}_b(\widehat{\alpha}p)$ and $\Delta Q^{\Sigma}_{HS} := Q^{\Sigma}_{\text{High-Low}} - Q^{\Sigma}_{\text{Strategic}} = \mu_s(\overline{F}(\widehat{\alpha}p) - \overline{F}_v(p)) + k(\widehat{\alpha})\sigma_s\overline{F}_v(\widehat{\alpha}p) - k\sigma_s\overline{F}_v(p) + N_b\overline{F}_b(\widehat{\alpha}p)$, we have that ΔQ^{Σ}_{HF} and ΔQ^{Σ}_{HS} are increasing in μ_s. Further, we have $\Delta Q^{\Sigma}_{HF}|_{\mu_s=0} \ge 0$, $\Delta Q^{\Sigma}_{HS}|_{\mu_s=0} \ge 0$, $\lim_{\mu_s\to+\infty}\Delta Q^{\Sigma}_{HF}(\mu_s) \ge 0$ and $\lim_{\mu_s\to+\infty}\Delta Q^{\Sigma}_{HS}(\mu_s) \ge 0$. Therefore, $\Delta Q^{\Sigma}_{HF} \ge 0$ and $\Delta Q^{\Sigma}_{HS} \ge 0$ always hold, which indicate that $Q^{\Sigma}_{\text{High-Low}}$ is the maximum.

To show which is the minimum, we need to compare $Q^{\Sigma}_{\text{Strategic}}$ and $Q^{\Sigma}_{\text{Fixed}}$. Note that $\Delta Q^{\Sigma}_{SF} := Q^{\Sigma}_{\text{Strategic}} - Q^{\Sigma}_{\text{Fixed}} = (\mu_s + k\sigma_s)\overline{F}_v(p)(1-\beta)$. It is clear that whether or not $\Delta Q^{\Sigma}_{SF} \ge 0$ is determined by the sign of $\mu_s + k\sigma_s$. Note that strategic market size is normally distributed. To ensure that the strategic market size is nonnegative, it usually assumes that $\mu_s \ge 3\sigma_s$. Under this assumption, $\mu_s + k\sigma_s \le 0$ can be rewritten as $k \le -3$ or $\frac{p-c}{p} \le \Phi(-3) \le 0.13\%$ which indicates that $\mu_s + k\sigma_s \le 0$ is impossible because the retailer hardly makes a profit at a margin of 0.13%. Therefore, $\Delta Q^{\Sigma}_{SF} \ge 0$ always holds. This completes the proof.

Appendix B. A Full Two-period Setting: A Numerical Investigation

In this section, we extend our study under a full two-period setting. We denote p_0 and c_0 are the selling price and cost per unit in season 0. At the beginning of season 0, the retailer need to decide the order quantity Q_0 for season 0. Since strategic consumer always wait for potential markdown sales, we assume that myopic demand is realized in advance. At the time that myopic demand is realized, the remaining inventory is $I = Q_0 - N_m\overline{F}(p_0)$. Under the fixed pricing strategy, the remaining inventory could be further sold at the full price. While under other two strategies, retailers set markdown discount and start markdown sale to inform strategic consumer their selling strategy and announce the fixed discount. Figure B.1 depicts the retailer's decisions in season 0.

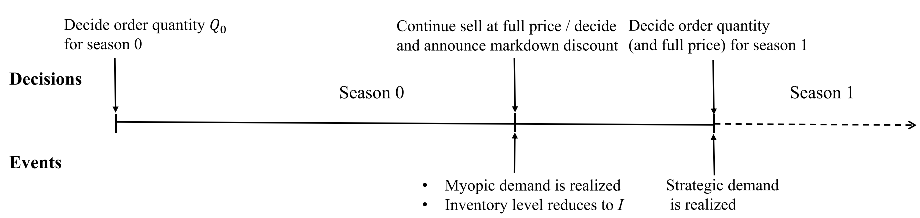

Fig. B.1. Timeline of decisions and events in Season 0.

To avoid overordering under the fixed-pricing strategy, the remaining inventory can be sold out at p_0, i.e., $I = Q_0 - N_m\overline{F}(p_0) \le \beta(\mu_s\overline{F}_v(p_0) + k_0\sigma_s\overline{F}_v(p_0))$ where $k_0 = \Phi^{-1}(\frac{p_0-c_0}{p_0})$ and $\beta(\mu_s\overline{F}_v(p_0) + k_0\sigma_s\overline{F}_v(p_0))$ is the optimal order quantity for selling to existing strategic consumer. To make the problem easy to exposition, we consider both p_0 and c_0 are exogenously given. The retailer first decides order quantity for season 1 to maximize the profit of period 1, and then decides Q_0, α and p to maximize total profits of two seasons. For a given p, the total order quantity of both seasons under each strategy is given as follows.

$$\begin{aligned}Q^{\Sigma}_{\text{Fixed}} &= \underbrace{N_m\overline{F}(p_0) + \beta(\mu_s\overline{F}_v(p_0) + k_0\sigma_s\overline{F}_v(p_0))}_{\text{Order quantity for season 0 } (Q_0)} + \underbrace{N_m\overline{F}_v(p) + \beta\mu_s\overline{F}_v(p) + \beta k\sigma_s\overline{F}_v(p)}_{\text{Order quantity for season 1}}\\ Q^{\Sigma}_{\text{Strategic}} &= \underbrace{N_m\overline{F}(p_0) + \mu_s\overline{F}_v(p_0) + k_0\sigma_s\overline{F}_v(p_0)}_{\text{Order quantity for season 0 } (Q_0)} + \underbrace{N_m\overline{F}_v(p) + \mu_s\overline{F}_v(p) + k\sigma_s\overline{F}_v(p)}_{\text{Order quantity for season 1}}\\ Q^{\Sigma}_{\text{High-Low}} &= \underbrace{N_m\overline{F}(p_0) + \mu_s\overline{F}_v(p_0) + k_0\sigma_s\overline{F}_v(p_0)}_{\text{Order quantity for season 0 } (Q_0)} + \underbrace{N_m\overline{F}_v(p) + N_b\overline{F}_b(\widehat{\alpha}p) + \mu_s\overline{F}_v(\widehat{\alpha}p) + k(\widehat{\alpha})\sigma_s\overline{F}_v(\widehat{\alpha}p)}_{\text{Order quantity for season 1}}\end{aligned}$$

Correspondingly, for a given p, the profit under different selling strategies are as follows:

$$\begin{aligned}\Pi_{\text{Fixed}} &= (p_0-c_0)(N_m\overline{F}(p_0)+\beta(\mu_s\overline{F}_v(p_0)+k_0\sigma_s\overline{F}_v(p_0)))\\ &\quad +(p-c)N_m\overline{F}_v(p)+\beta((p-c)\mu_s\overline{F}_v(p)-p\sigma_s\varphi(k)\overline{F}_v(p));\\ \Pi_{\text{Strategic}} &= (p_0-c_0)(N_m\overline{F}(p_0)+\mu_s\overline{F}_v(p_0)+k_0\sigma_s\overline{F}_v(p_0))-(1-\overline{\alpha})p_0(\mu_s\overline{F}_v(p_0)+k_0\sigma_s\overline{F}_v(p_0))\\ &\quad +(p-c)N_m\overline{F}_v(p)+(p-c)\mu_s\overline{F}_v(p)-p\varphi(k)\sigma_s\overline{F}_v(p);\\ \Pi_{\text{High-Low}} &= (p_0-c_0)(N_m\overline{F}(p_0)+\mu_s\overline{F}_v(p_0)+k_0\sigma_s\overline{F}_v(p_0))-(1-\widehat{\alpha})p_0(\mu_s\overline{F}_v(p_0)+k_0\sigma_s\overline{F}_v(p_0))\\ &\quad +(p-c)N_m\overline{F}_v(p)+(\widehat{\alpha}p-c)N_b\overline{F}_b(\widehat{\alpha}p)+(\widehat{\alpha}p-c)\mu_s\overline{F}_v(\widehat{\alpha}p)-\widehat{\alpha}p\varphi(k(\widehat{\alpha}))\sigma_s\overline{F}_v(\widehat{\alpha}p).\end{aligned}$$

By numerically solving the first-order conditions of Π_{Fixed}, $\Pi_{\text{Strategic}}$ and $\Pi_{\text{High-Low}}$, we can derive the optimal selling prices in season 1 and their corresponding maximal profits. Parameter settings are as follows: $N_m = 60$, $\beta = 0.6$, $N_b = 60$, $\sigma_s = 60$, $V \sim N(6, 3^2)$, $V_b \sim N(5, 5.5^2)$, $\overline{\alpha} = 70\%$, $\lambda = 0.076$, $p_0 = 6$ and $c_0 = 2$. We vary the purchasing cost $c \in [1, 5]$ and consider the market size $\mu_s \in \{20, 180\}$ side by side. From Tables B.1 and B.2, it is clear that the structural results carry over under a full two-period setting. More specifically, high-low pricing is best only if the offered discount is small. Otherwise, whether fixed pricing is best relies on the strategic market size.

Table B.1
Optimal prices and maximal profit with a small strategic market size $\mu_s = 20$

	High-Low Pricing			Fixed Pricing		Strategic High Pricing	
Cost	Discount(%)	Price in season 1	Profit	Price in season 1	Profit	Price in season 1	Profit
c	$1-\widehat{\alpha}$	$(p, \widehat{\alpha}p)$	$\Pi_{\text{High-Low}}$	p	Π_{Fixed}	p	$\Pi_{\text{Strategic}}$
1.0	43.3%	(10.39, 5.89)	324.55	5.67	**329.10**	5.85	325.82
1.5	39.4%	(10.74, 6.51)	298.82	5.98	**302.70**	6.15	293.46
2.0	36.0%	(11.09, 7.10)	279.18	6.24	**280.29**	6.55	267.11
2.5	33.0%	(11.44, 7.66)	**264.18**	6.56	261.19	6.84	245.60
3.0	30.4%	(11.79, 8.20)	**252.72**	6.88	244.95	7.24	228.14
3.5	30.1%	(11.83, 8.27)	**240.08**	7.20	231.20	7.64	214.08
4.0	30.8%	(11.73, 8.11)	**225.85**	7.52	219.65	8.04	202.89
4.5	30.5%	(11.77, 8.18)	**215.54**	7.89	210.05	8.44	194.12
5.0	30.2%	(11.82, 8.25)	**206.51**	8.21	202.15	8.94	187.37

Table B.2
Optimal prices and maximal profit with a big strategic market size $\mu_s = 180$

	High-Low Pricing			Fixed Pricing		Strategic High Pricing	
Cost	Discount(%)	Price in season 1	Profit	Price in season 1	Profit	Price in season 1	Profit
c	$1-\widehat{\alpha}$	$(p, \widehat{\alpha}p)$	$\Pi_{\text{High-Low}}$	p	Π_{Fixed}	p	$\Pi_{\text{Strategic}}$
1.0	45.2%	(10.24, 5.61)	831.35	5.55	765.43	5.55	**908.61**
1.5	44.7%	(10.29, 5.69)	757.17	5.74	711.84	5.74	**830.51**
2.0	42.3%	(10.48, 6.05)	702.93	6.00	663.74	6.04	**761.06**
2.5	40.1%	(10.68, 6.40)	654.83	6.32	620.54	6.34	**699.05**
3.0	38.0%	(10.88, 6.74)	612.47	6.58	581.87	6.64	**643.88**
3.5	36.1%	(11.08, 7.07)	575.52	6.83	547.43	6.93	**595.08**
4.0	34.4%	(11.27, 7.39)	543.61	7.15	517.01	7.23	**552.22**
4.5	32.8%	(11.47, 7.71)	**516.38**	7.47	490.35	7.53	514.92
5.0	31.3%	(11.67, 8.02)	**493.44**	7.79	467.24	7.83	482.76

References

Adida, E., Özer, O., 2019. Why markdown as a pricing modality? Manag. Sci. 65, 2161–2178.
Altug, M.S., Aydinliyim, T., 2016. Counteracting strategic purchase deferrals: the impact of online retailers return policy decisions. Manuf. Serv. Oper. Manag. 18, 376–392.
Ang, K., 2016. Good Luck Finding Luxury Brands like Louis Vuitton, Hermès or Even Tesla on Sale. www.marketwatch.com/story/good-luck-finding-these-luxury-brands-on-sale-2016-12-28.
Arifoğlu, K., Deo, S., Iravani, S.M.R., 2020. Markdowns in seasonal conspicuous goods. Market. Sci. 39, 1016–1029.
Aviv, Y., Pazgal, A., 2008. Optimal pricing of seasonal products in the presence of forward-looking consumers. Manuf. Serv. Oper. Manag. 10, 339–359.
Aviv, Y., Wei, M.M., Zhang, F., 2019. Responsive pricing of fashion products: the effects of demand learning and strategic consumer behavior. Manag. Sci. 65, 2982–3000.
Bai, T., Wu, M., Zhu, S.X., 2019. Pricing and ordering by a loss averse newsvendor with reference dependence. Transport. Res. E Logist. Transport. Rev. 131, 343–365.
Besanko, D., Winston, W.L., 1990. Optimal price skimming by a monopolist facing rational consumers. Manag. Sci. 36, 555–567.
Cachon, G.P., Feldman, P., 2015. Price commitments with strategic consumers: why it can be optimal to discount more frequently than optimal. Manuf. Serv. Oper. Manag. 17, 399–410.
Cachon, G.P., Swinney, R., 2009. Purchasing, pricing, and quick response in the presence of strategic consumers. Manag. Sci. 55, 497–511.
Caro, F., Gallien, J., 2012. Clearance pricing optimization for a fast-fashion retailer. Oper. Res. 60, 1404–1422.
Chevalier, J., Goolsbee, A., 2009. Are durable goods consumers forward-looking? Evidence from college textbooks. Q. J. Econ. 124, 1853–1884.
Coase, R., 1972. Durability and monopoly. J. Law Econ. 57, 143–149.
Correa, J., Montoya, R., Thraves, C., 2016. Contingent preannounced pricing policies with strategic consumers. Oper. Res. 64, 251–272.
Dong, J., Wu, D.D., 2019. Two-period pricing and quick response with strategic customers. Int. J. Prod. Econ. 215, 165–173.
Elmaghraby, W., Gülcü, A., Keskinocak, P., 2008. Designing optimal preannounced markdowns in the presence of rational customers with multiunit demands. Manuf. Serv. Oper. Manag. 10, 126–148.
Elmaghraby, W., Lippman, S.A., Tang, C.S., Yin, R., 2009. Will more purchasing options benefit customers? Prod. Oper. Manag. 18, 381–401.
Fay, S., Xie, J., 2010. The economics of buyer uncertainty: advance selling vs. probabilistic selling. Market. Sci. 29, 1040–1057.

Ferdows, K., Machuca, J., Lewis, M., 2002. Zara. The European case clearing house. Case 603-002-1.
Gallego, G., van Ryzin, G., 1994. Optimal dynamic pricing of inventories with stochastic demand over finite horizons. Manag. Sci. 40, 999–1020.
Ghemawat, P., Nueno, J.L., 2003. Zara: Fast Fashion. Harvard Business School Multimedia Case 9-703-416.
Hendricks, K.B., Singhal, V.R., 2014. The effect of demand-supply mismatches on firm risk. Prod. Oper. Manag. 23, 2137–2151.
Ho, T.-H., Savin, S., Terwiesch, C., 2002. Managing demand and sales dynamics in new product diffusion under supply constraint. Manag. Sci. 48, 187–206.
Hu, P., Shum, S., Yu, M., 2016. Joint inventory and markdown management for perishable goods with strategic consumer behavior. Oper. Res. 64, 118–134.
Kaufmann, P., Smith, N., Ortmeyer, G., 1994. Deception in retailer high-low pricing: a rule of reason approach. J. Retailing 70, 115–138.
Kremer, M., Mantin, B., Ovchinnikov, A., 2017. Dynamic pricing in the presence of myopic and strategic consumers: theory and experiment. Prod. Oper. Manag. 26, 116–133.
Kumar, S., Swaminathan, J.M., 2003. Diffusion of innovations under supply constraints. Oper. Res. 51, 866–879.
Lai, G., Debo, L.G., Sycara, K., 2010. Buy now and match later: impact of posterior price matching on profit with strategic consumers. Manuf. Serv. Oper. Manag. 12, 33–55.
Levin, Y., McGill, J., Nediak, M., 2010. Optimal dynamic pricing of perishable items by a monopolist facing strategic consumers. Prod. Oper. Manag. 19, 40–60.
Levina, T., Levin, Y., McGill, J., Nediak, M., 2009. Dynamic pricing with online learning and strategic consumers: an application of the aggregating algorithm. Oper. Res. 57, 327–341.
Li, C., Zhang, F., 2013. Advance demand information, price discrimination, and preorder strategies. Manuf. Serv. Oper. Manag. 15, 57–71.
Li, Q., Yu, P., 2014. Multimodularity and its applications in three stochastic dynamic inventory problems. Manuf. Serv. Oper. Manag. 16, 455–463.
Lim, W.S., Tang, C.S., 2013. Advance selling in the presence of speculators and forward-looking consumers. Prod. Oper. Manag. 22, 571–587.
Liu, Q., van Ryzin, G.J., 2008. Strategic capacity rationing to induce early purchases. Manag. Sci. 54, 1115–1131.
Ma, S., Li, G., Sethi, S.P., Zhao, X., 2019. Advance selling in the presence of market power and risk-averse consumers. Decis. Sci. J. 50, 142–169.
Mersereau, A.J., Zhang, D., 2012. Markdown pricing with unknown fraction of strategic customers. Manuf. Serv. Oper. Manag. 14, 355–370.
Muth, J.F., 1961. Rational expectations and the theory of price movements. Econometrica 29, 315–335.
Nair, H., 2007. Intertemporal price discrimination with forward-looking consumers: application to the us market for console video-games. Quant. Market. Econ. 5, 239–292.
Nasiry, J., Popescu, I., 2012. Advance selling when consumers regret. Manag. Sci. 58, 1160–1177.
Osadchiy, N., Bendoly, E., 2015. Are Consumers Really Strategic? Implications from an Experimental Study (Working paper).
Osadchiy, N., Vulcano, G., 2010. Selling with binding reservations in the presence of strategic consumers. Manag. Sci. 56, 2173–2190.
Ovchinnikov, A., Milner, J.M., 2012. Revenue management with end-of-period discounts in the presence of customer learning. Prod. Oper. Manag. 21, 69–84.
Papanastasiou, Y., Savva, N., 2017. Dynamic pricing in the presence of social learning and strategic consumers. Manag. Sci. 63, 919–939.
Prasad, A., Stecke, K.E., Zhao, X., 2011. Advance selling by a newsvendor retailer. Prod. Oper. Manag. 20, 129–142.
Reagan, C., 2015. Bye-bye, High-End Handbag Discounts. www.cnbc.com/2015/08/07/bye-bye-high-end-handbag-discounts.html.
Shen, B., Xu, X., Choi, T.-M., 2019. Simplicity is beauty: pricing coordination in two-product supply chains with simplest contracts under voluntary compliance. Int. J. Prod. Res. 57, 2769–2787.
Shen, B., Zhang, T., Xu, X., Chan, H.-L., Choi, T.-M., 2020. Preordering in luxury fashion: will additional demand information bring negative effects to the retailer? Decis. Sci. J. https://doi.org/10.1111/deci.12491.
Shen, W., Duenyas, I., Kapuscinski, R., 2011. New product diffusion decisions under supply constraints. Manag. Sci. 57, 1802–1810.
Silver, E., Pyke, D., Peterson, R., 1998. Inventory Management and Production Scheduling. Wiley.
Smith, K., 2014. Summer Sales: the Discounting Lowdown. blog.edited.com/blog/resources/summer-sales-the-discounting-lowdown.
Stokey, N.L., 1979. Intertemporal price discrimination. Q. J. Econ. 93, 355–371.
Stokey, N.L., 1981. Rational expectations and durable goods pricing. Bell J. Econ. 12, 112–128.
Su, X., 2007. Intertemporal pricing with strategic customer behavior. Manag. Sci. 53, 726–741.
Su, X., 2010a. Intertemporal pricing and consumer stockpiling. Oper. Res. 58, 1133–1147.
Su, X., 2010b. Optimal pricing with speculators and strategic consumers. Manag. Sci. 56, 25–40.
Su, X., Zhang, F., 2008. Strategic customer behavior, commitment, and supply chain performance. Manag. Sci. 54, 1759–1773.
Surasvadi, N., Tang, C.S., Vulcano, G., 2017. Using contingent markdown with reservation to profit from strategic consumer behavior. Prod. Oper. Manag. 26, 2226–2246.
Talluri, K., van Ryzin, G., 2004. The Theory and Practice of Revenue Management. Springer.
Tereyağoğlu, N., Veeraraghavan, S., 2012. Selling to conspicuous consumers: pricing, production, and sourcing decisions. Manag. Sci. 58, 2168–2189.
Voeth, M., Herbst, U., 2006. Supply-chain pricing–A new perspective on pricing in industrial markets. Ind. Market. Manag. 35, 83–90.
Wei, M.M., Zhang, F., 2018. Recent research developments of strategic consumer behavior in operations management. Comput. Oper. Res. 93, 166–176.
Wu, M., Teunter, R.H., Zhu, S.X., 2019. Online marketing: when to offer a refund for advanced sales. Int. J. Res. Market. 36, 471–491.
Wu, M., Zhu, S.X., Teunter, R.H., 2021. Advance selling and advertising: a newsvendor framework. Decis. Sci. J. 52, 182–215.
Wu, S., Liu, Q., Zhang, R.Q., 2015. The reference effects on a retailer dynamic pricing and inventory strategies with strategic consumers. Oper. Res. 63, 1320–1335.
Xu, J., Duan, Y., 2020. Pricing, ordering, and quick response for online sellers in the presence of consumer disappointment aversion. Transport. Res. E Logist. Transport. Rev. 137, 101925.
Yuan, Q., Shen, B., 2019. Renting fashion with strategic customers in the sharing economy. Int. J. Prod. Econ. 218, 185–195.
Zhang, D., Cooper, W.L., 2008. Managing clearance sales in the presence of strategic customers. Prod. Oper. Manag. 17, 416–431.
Zhao, X., Stecke, K.E., 2010. Pre-orders for new to-be-released products considering consumer loss aversion. Prod. Oper. Manag. 19, 198–215.