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Review

Recent research developments of strategic consumer behavior in operations management

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ABSTRACT

Strategic consumer behavior has been extensively studied in the Management Science and Operations Management community. We survey recent developments in the literature and review possible operational strategies and decisions to counteract the adverse impact of strategic consumer behavior. Specifically, we broadly characterize these decisions into three classes – Pricing, Inventory, and Information – and further discuss the influence of strategic consumer behavior on these decisions and their underlying mechanisms on counteracting consumers' strategic waiting behavior.

1. Introduction

Technological advances have accelerated the adoption of dynamic pricing practice in industries such as retail, airline, and hotel, and trained consumers to time their purchases strategically for anticipated future discounts. Strategic consumer behavior has been an extensively discussed topic in the literature since (Coase, 1972), who argues that a monopolist's profit will be negatively influenced if consumers, anticipating future price drops, postpone their purchases – the idea of *strategic consumer behavior*. Since then, strategic consumer behavior has been empirically observed and studied for various industries such as console video games (Nair, 2007), textbooks (Chevalier and Goolsbee, 2009), soft drinks (Hendel and Nevo, 2013), and airline tickets (Li et al., 2014). In a controlled laboratory environment, Osadchiy and Bendoly (2015) find that facing a future purchase opportunity, up to 79% of customers exhibit strategic behavior. Furthermore, as strategic consumers will prefer to buy later at discounted prices instead of paying premium prices up-front, the literature overwhelmingly demonstrates that firms will significantly suffer from strategic consumer behavior. It is noteworthy, however, that being strategic may not necessarily benefit consumers. For example, Aflaki et al. (2016) demonstrate that depending on their valuations, many consumers will have lower surplus if they choose to behave strategically than if they are myopic.

The negative impact of strategic consumer behavior on the seller's profitability has been ubiquitously documented in the literature. For example, Coase (1972) argues that the monopolist cannot effectively exercise price discrimination on durable goods, because if the consumers rationally anticipate a price drop in the future, they will postpone their purchases. Following this logic, Coase (1972) conjectures that the only price at which the monopolist can expect to sell its products is the clearance price. This means that strategic consumer behavior results not only in the lack of ability to exercise discrimination, but the monopolist completely loses market power in the sense that it cannot even charge the best fixed price. Similar observations that the seller's ability to adjust future prices can be exploited by consumers, who wait strategically for future discounts to avoid paying the premium price up-front, have been extensively reported in the literature (e.g., Besanko and Winston, 1990; Elmaghraby et al., 2008; Stokey, 1979, and Su, 2007. Therefore, explicitly integrating strategic consumer behavior into the seller's decision-making processes is vital to the firm's profit performance, as ignoring strategic consumer behavior by incorrectly assuming that strategic customers are myopic can be quite costly – reaching a potential revenue loss of about 20% (Aviv and Pazgal, 2008). Hence, identifying tactics and strategies to counteract the adverse impact of strategic consumer behavior becomes a central research question in the strategic consumer behavior literature and will also be the focus of this review paper.

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Review papers and book chapters on the subject of strategic consumer behavior have been written by Chen and Chen (2015), Gönsch et al. (2013) , Netessine and Tang (2009), Özer and Phillips (2012), Shen and Su (2007), Tang (2010), and Zhou and Wu (2011). Most of these review papers or chapters focus on selective research papers or on specific domains. For example, each chapter in Netessine and Tang (2009) provides a detailed summary of the model setting, analysis, and major insights for highly concentrated research papers. Chapters in Özer and Phillips (2012) focus their discussions on the influence of strategic consumer behavior on the firms' pricing decisions. Tang (2010) includes a section discussing the impact of strategic consumers on marketing-operations models. Chen and Chen (2015) review selective papers and focus on the revenue management domain. In their review paper on dynamic pricing research, Zhou and Wu (2011) include the discussions of strategic consumer behavior as a recent research trend and possible future research direction. Among these review papers and chapters, Gönsch et al. (2013) and Shen and Su (2007) provide systematic and comprehensive reviews on strategic consumer behavior from angles that are different from ours. Gönsch et al. (2013) focus on reviewing how different model choices and assumptions in strategic consumer behavior literature influence managerial insights. Shen and Su (2007) present a detailed review of strategic consumer behavior in the revenue management domain prior to 2007. In this review paper, to avoid duplications, we will mainly focus on recent research papers (i.e., after 2007) in the Management Science and Operations Management discipline and concentrate on the development of tactics and strategies that have the potential to counteract the negative influence of strategic consumer behavior.

2. Review framework

In this section, we will illustrate strategic consumer behavior and categorize possible mechanisms to counteract such behavior via a stylized two-period decision-marking model. To this end, we first highlight the behavior differences between strategic consumers and non-strategic/myopic consumers. Suppose a monopolist sells a product in a two-period horizon. Consider a typical consumer who arrives in the first period. If this consumer decides to purchase immediately, facing the first-period price p_1 and first-period inventory level Q_1, she will gain a surplus of

$$S_1 \doteq \mathrm{E}[A_1 \cdot (v_1 - p_1)],$$

where v_1 denotes this consumer's first-period valuation/willingness-to-pay for this product and A_1 is the rationing probability function in the first period (i.e., the probability of obtaining the product in the first period). There are various allocation mechanism that determines how this strategic consumer can obtain a unit. For example, Aviv and Pazgal (2008) adopt a random allocation mechanism in which all consumers have equal probability to obtain a unit (i.e., the rationing probability is $\min\left\{1, \frac{Q_1}{D_1(p_1)}\right\}$, where $D_1(p_1)$ is the first-period demand function induced by the first-period price p_1), and Su (2010b) uses a valuation contingent allocation mechanism where products are allocated to consumers in the order of their valuations. If this consumer is myopic, then she will purchase as long as her surplus from the immediate purchase is non-negative (i.e., $S_1 \geq 0$). That is, myopic consumers will delay their purchases when their surpluses from immediate purchases are negative ($S_1 < 0$).

Strategic consumers, on the other hand, can intentionally delay their purchases and strategically wait for anticipated future discounts, even though the surplus from the immediate purchase is non-negative ($S_1 \geq 0$). Specifically, based on her anticipated second-period price p_2 and inventory level Q_2, a strategic consumer will assess the expected surplus from a wait decision to be

$$S_2 \doteq \mathrm{E}[A_2 \cdot \max\{0, (v_2 - p_2)\}],$$

where v_2 is the consumer's second-period valuation and A_2 is the rationing probability function in the second period. Depending on the allocation mechanisms, this rationing probability function can be contingent both on first-period parameters (e.g., Q_1, $D_1(p_1)$, p_1, and v_1) and on second-period parameters, such as the second-period demand $D_2(p_1, D_1(p_1), p_2)$, price p_2, inventory level Q_2, and valuation v_2. The strategic consumer will purchase immediately, only if the surplus from the immediate purchase is no less than that from a wait decision (i.e., $S_1 \geq S_2 \geq 0$) ; otherwise (i.e., $S_2 > S_1$), she will wait for the second period (even though the surplus from the immediate purchase may be non-negative, i.e., $S_1 \geq 0$) – the *strategic waiting behavior*.

Intuitively, to mitigate strategic waiting behavior, the seller should suppress consumers' expected surpluses from waiting (i.e., decrease S_2). The structure of S_2 provides the seller two approaches: limiting the surplus associated with obtaining a product with a lower second-period price (i.e., reduce $\max\{0, (v_2 - p_2)\}$) or restricting the probability of obtaining the product in the second period (i.e., reduce A_2). The former approach can be achieved by carefully selecting the seller's pricing decisions (e.g., p_1 and p_2), and the latter approach can be accomplished by optimally determining the seller's inventory decisions (e.g., Q_1 and Q_2) and information decisions (e.g., reveal or hide product availability information). Therefore, we broadly characterize firm decisions into three classes: *Pricing, Inventory* , and *Information*. Note that these three classes are not necessarily exclusive, and research papers have included decisions from multiple classes to better mitigate strategic waiting behavior. Yet, the underlying mechanisms and rationals reviewed in this paper for each class will remain unchanged.

Specifically, we first characterize strategies that curb the negative influence of strategic consumer behavior by limiting price changes (i.e., via controlling p_1 and p_2) as the *Pricing* class. For example, the seller could fix two period prices to be the same (i.e., $p_1 = p_2$) to remove consumers' incentives from waiting for possible future discounts (e.g., see Su and Zhang, 2008 for the fixed price strategy); the seller could announce a future price path (i.e., p_1 and p_2 are announced and committed at the beginning of the selling season) to discourage strategic waiting behavior by committing to a high second-period price (e.g., see Aviv and Pazgal, 2008 for the price-commitment strategy); the seller could assure early purchasing consumers the best price by offering to match the price difference (i.e., reimburse $\max\{0, p_1 - p_2\}$ to consumers, if the seller lowers its future price) (e.g., see Lai et al., 2010 for the price-matching strategy). We will explore these pricing decisions in Section 3.

Another class of strategies to counteract strategic waiting behavior by limiting product availability (via controlling Q_1 and Q_2) can be characterized as the *Inventory* class. For example, through intentionally understock inventory (e.g., see Liu and Van Ryzin, 2008), the seller could suppress the rationing probability, and the strategic consumer who contemplates an immediate purchase vs. a wait decision will incline to purchase early due to the concern that the product might not be available anymore in the second period. We will detail the influence of inventory decisions on strategic consumer behavior in Section 4 .

Similar to inventory decisions, the seller could also adopt the last class of strategies, the *Information* class, to influence strategic consumers' perceptions about the product availability. For example, the seller may choose to display partial inventory information, instead of full inventory information, to increase the perceived product scarcity to discourage strategic waiting behavior (Yin et al., 2009), or the seller could intentionally hide product information and dispose unsold units through an opaque chan-

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nel to curb consumers' perception about the product availability (Jerath et al., 2010). The impact of these information decisions on consumers' behavior will be reviewed in Section 5. Finally, we will conclude this paper by discussing possible future research directions in Section 6.

3. Pricing

Recent research on strategic consumer behavior has explored and developed various pricing strategies to counteract strategic consumer behavior, such as responsive pricing strategy (Cachon and Swinney, 2009), fixed price strategy (Su and Zhang, 2008), inter-temporal price matching strategy (Lai et al., 2010), and price commitment strategy (Aviv and Pazgal, 2008), etc. In the following, we will discuss the influence of strategic consumer behavior under these pricing strategies and their mechanisms and effectiveness on counteracting consumers' strategic waiting behavior.

3.1. Responsive pricing

When there is no strategic waiting behavior, the firm benefits from the ability to adjust its prices in the future as more information become available. In particular, the firm could dynamically change its prices in response to newly available information such as consumers' purchasing decisions, sales data, and inventory levels. We, therefore, will use responsive pricing and dynamic pricing interchangeably to highlight the fact that dynamic price changes are in response to new information. However, without committing to future prices in advance or limiting the extent of future price changes, responsive pricing strategy could be explored by strategic consumers: Realizing that the firm could lower its prices in the future when there is ample leftover inventory, consumers will postpone their purchasing decisions and wait strategically for future discounts. In other words, fewer consumers will purchase at the premium price, and the seller's ability to offer different prices as a market segmentation mechanism becomes less effective (Coase, 1972).

Responsive pricing is a commonly observed pricing strategy in practice. It is not only because the firm may lack commitment power to adopt other pricing strategies (e.g., pre-announced pricing and price matching strategy), but also because the optimal prices under dynamic pricing strategy are often stable and facilitate consumers to learn and anchor their estimations for future prices. For example, Wu et al. (2015) propose a consumer's heuristic model in estimating markdown prices. In particular, strategic consumers do not exactly know the firm's future prices when they time their purchases. Instead, they may rely on past prices to anchor their estimation – the reference price. Wu et al. (2015) demonstrate the stability of their model by pointing out that in the long run, the reference and dynamic prices have steady state distributions under general conditions.

One of the potential benefits of responsive pricing strategy is that the firm could learn the market demand via sales data and improve its future pricing decisions. The literature has proposed models to incorporate such learning into the dynamic pricing practice. For example, Levina et al. (2009) study a monopolistic firm who can dynamically price a perishable product and simultaneously learn the market via an aggregating algorithm. They demonstrate via numerical studies that the learning procedure is quite robust to deviations of the actual market. In the majority of dynamic pricing literature, the ability to adjust future prices based on updated demand information can benefit the firm. However, such learning ability may not necessarily benefit the firm when consumers are strategic. Aviv et al. (2016) study a Bayesian learning model and demonstrate that the firm's ability to learn about the market size can intensify strategic waiting behavior and hence hurt the firm's revenue performance due to the information shaping effect. Chen and Wang (2016) find that the firm's ability to learn about consumers' valuations can be undermined by strategic waiting behavior. They propose a randomized Bayesian policy, which learns and updates the belief of consumers' valuation in each period with a certain probability, to completely learn consumers' valuations in the long run. Huang et al. (2017) investigate the relationship between demand learning and preference learning under the context of mass customizations (Cil and Pangburn, 2017). They argue that these two learning effects can be either complements or substitutes, and under strategic consumer behavior, the substitute effect tends to dominate for fashionable products (i.e., consumers' valuations decrease quickly).

Besides the firm, consumers can also learn signals from early sales. Papanastasiou and Savva (2016) consider a setting in which strategic consumers could delay their purchases to learn products' quality from online reviews (social learning). Under this setting, they demonstrate that responsive pricing strategy is preferred over the non-responsive pricing strategy (e.g., pre-announced pricing strategy). Due to social learning, the optimal responsive pricing policy consists of an initial low price to accelerate the learning process by encouraging more online reviews, and then depending on the revealed quality perception, the firm could either raise or lower prices later. Further, they find that social learning will improve the firm's profit, despite the fact that social learning may encourage strategic waiting behavior to some extent. Feldman et al. (2016) extend this line of research to consider the optimal product quality design. They find that social learning could have a negative impact on the firm's profit, and it is optimal for the firm to opt for a low quality design.

Merely relying on responsive pricing strategy may not effectively counteract strategic consumer behavior, but when responsive pricing strategy is adopted together with the capacity decision, the strategic consumer behavior could be effective contained. For example, Levin et al. (2010) study the optimal dynamic pricing strategy in a continuous time setting. They demonstrate that limiting initial capacity together with optimal dynamic pricing decisions is crucial for effectively curbing the negative effects of strategic consumer behavior.

3.2. Pre-announced pricing

The firm could pro-actively announce their future pricing schedules at the beginning of a selling season (i.e., pre-announced pricing strategy). By committing to a smaller discount in the future, the firm could limit price differences and therefore discourage strategic waiting incentives. For example, Filene's Basement is known for its pre-announced pricing policy. At the Filene's Basement Boston store, unsold products will be offered at 25%, 50%, and 75% off their original prices after two, four, and six weeks, respectively. After two months, the remaining unsold items will be donated to charity (Bell and Starr, 1993). Additional examples of pre-announced pricing strategy include Lands' End Overstocks' On the Counter website, Dress for Less, Tuesday Morning discount stores, Wanamaker discount department store in Philadelphia, and TKTS ticket booths in New York City (Yin et al., 2009).

When compared to responsive pricing strategy, pre-announced pricing strategy can benefit the firm through mitigating strategic consumer behavior. Aviv and Pazgal (2008) study and compare two types of markdown strategies: pre-announced pricing strategy and responsive pricing strategy. They find that as expected, a flexible and information-dependent responsive pricing strategy performs better for the firm than the pre-announced strategy when consumers are myopic. Yet, pre-announced pricing strategy could be advantageous to the seller and performs better than responsive

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pricing strategy under strategic consumer behavior. They show that strategic consumer behavior affects the seller's ability to effectively perform price segmentation, and this influence persists even under low levels of initial inventory. They further point out that it is important to endogenize strategic consumer behavior consideration in the firm's decision-making process, as ignoring strategic consumer behavior and incorrectly assuming them to be myopic could cause potential revenue losses as high as 20%. Extending Aviv and Pazgal (2008) where there is one price change allowed, Dasu and Tong (2010) study a model that permits multiple price adjustments. They show that limiting the number of price changes will decrease the firm's revenue performance. Yet, the number of price changes need not be large, and two or three price changes are sufficient enough to achieve a near optimal revenue performance.

Instead of announcing a fixed price that is not responsive to newly revealed information in the future, the firm could reinstall certain responsiveness to pre-announced pricing strategy by announcing a price menu that is contingent on sales or future inventory levels. Correa et al. (2016) propose such a pre-announced pricing menu and develop a novel gradient-based method to solve the firm's price optimization problem. Through numerical experiments, they show that this proposed inventory contingent pre-announced pricing strategy outperforms the non-contingent pre-announced pricing strategy with revenue improvements up to 4.4%.

Pre-announced pricing strategy could be robust to market uncertainty and does not necessarily require precise market knowledge of strategic behavior to perform well. In particular, when the fraction of strategic customers in the market is unknown, Mersereau and Zhang (2012) propose a robust pre-announced pricing strategy, which minimizes the maximum relative revenue loss over all possible fractions of strategic consumers in the market. They show that this robust pre-announced pricing strategy, while requiring no prior knowledge of the fraction of strategic consumers, performs well.

However, pre-announced pricing strategy might be costly and sub-optimal when the firm possesses the opportunity to learn the demand and replenish its inventory before the selling season begins. Cachon and Swinney (2009) develop a model in which the firm has the quick response ability to procure additional inventory at a higher unit cost than the initial order after learning the precise demand information before the selling season begins. They argue that pre-announced pricing strategy is often too costly as inventory may remain unsold at the end of the second period. Instead, responsive pricing strategy together with the quick response ability could better match the supply with demand and improve the sellers profitability.

3.3. Fixed pricing

Broadly speaking, fixed pricing strategy can be treated as a special case of pre-announced pricing strategy in which the firm announces it will keep prices unchanged in the future. Yet, fixed pricing strategy is extensively mentioned and benchmarked in the strategic consumer behavior literature, due to its simple structure and popularity in practice. Moreover, we will see that under certain conditions, optimal pre-announced pricing strategy could converge to fixed pricing strategy. Therefore, we will dedicate this subsection to fixed pricing strategy.

Stokey (1979) considers a monopolist who is able to credibly commit to a price path during a continuous time selling season and shows that (for the case of zero production cost) it is optimal for the firm to only sell products at the beginning of selling season and forgo the opportunity to perform price discrimination. In other words, optimal pre-announced pricing strategy actually takes the form of a fixed pricing policy. Whang (2014) studies pre-announced pricing strategy under a linear demand function in which parameters of the function can be learned by consumers via Bayesian method, and derived the optimal pricing scheme. In addition, the author shows that when there is no parameter uncertainty (e.g., parameters for the demand function are common knowledge), it is optimal to announce the same price for both periods (i.e., a fixed pricing strategy).

Su (2010a) studies a dynamic pricing problem for products with stable and repetitive consumption patterns over an infinite time horizon. Consumers are strategic and may stock up products for future consumption. The author shows that fixed pricing strategy prevails, and the price promotions (i.e., variable prices) should be used only when frequent buyers possess a higher willingness to pay.

Fixed pricing strategy is particularly effective when there are speculators who enter the market purely with the intention to resell products. Su (2010b) demonstrates that the presence of speculators increases the firm's profit even though they may compete with the firm for strategic consumers in the second period. Further, while charging the fixed price, the firm could effectively enjoy the benefits of price discrimination, thanks to the resale by speculators. In a market that comprises myopic consumers, strategic consumers, and speculators, Lim and Tang (2013) argue that fixed pricing strategy is optimal for an upward market where the expected valuation increases over time. Even under a downward market, fixed pricing strategy continues to be optimal, if the first-period sales could induce more demand in the second period and the expected valuation does not decrease too much.

To successfully implement fixed pricing strategy, the firm must possess certain commitment power to not mark down price in the future. For example, Su and Zhang (2008) show that fixed pricing strategy could improve the firm's profit over a markdown strategy. The authors point out that the commitment to fixed pricing strategy may not be credible, as the firm will find it profitable later on in the season to adjust its price downward to segment the market. Therefore, Su and Zhang (2008) discuss possible commitment devices, such as decentralized supply chain and contracts (e.g., markdown money, sales rebates, and buyback contracts), to attain the desired commitment outcomes.

3.4. Price matching

The firm may completely eliminate strategic waiting behavior by adopting an inter-temporal price matching strategy: The firm guarantees to reimburse the price difference for a consumer who purchases a product at the premium price and finds that the seller discounts the price later. In practice, the price matching strategy started to proliferate in the early 1980s in consumer electronics, auto, discount stores, retail, manufacturing, and financial markets (Edlin, 1997). Essentially, under such a strategy, the firm agrees to match the price difference at any time in the future if the price ever decreases. Therefore, consumers will no longer be concerned about their purchase timing and will buy the product as long as their expected surplus from an immediate purchase is non-negative (i.e., behave myopically). Besides eliminating strategic waiting behavior, another benefit of the price matching strategy is that it allows the seller to increase the firm's premium price in the early selling season. Yet, the downside is that, by promising to reimburse the price differences, price matching strategy limits the seller's options to adjust its prices downward later, as doing so is at the cost of issuing a refund to consumers who purchase earlier.

Lai et al. (2010) study the benefits of price matching strategy and compare it to responsive pricing strategy in a market consisting of both strategic and myopic consumers. They find that when the fraction of strategic consumers is not too small and their valuations decline at a medium rate, price matching strategy could

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significantly improve the firm's profit. In addition, the performance of price matching strategy is insensitive to the proportion of consumers who actually claim the refund when the firm lowers its price at the end of selling season. Further, price matching strategy could be a Pareto improvement on both the firm's profitability and consumers' surplus, especially when the variance of the market size of the high-valuation consumers is high. Note that the firm may not need to match the full amount of the price difference (e.g., see Li and Zhang, 2013 for a model of the optimal level of partial price match).

Similar to price matching strategy, the firm could partially reimburse consumers who purchase early at the premium price by offering a return option. Altug and Aydinliyim (2016) propose a model in which strategic consumers are uncertain about their valuations early in the season. They demonstrate that allowing returns and offering a generous refund could induce more sales at the premium price by mitigating consumers' early-purchase regret and signaling clearance unavailability risk. Further, they find that the refund policy does not need to be exceedingly generous to deter strategic waiting behavior, and the optimal refund amount is typically lower than the clearance price. Different from price matching strategy, in which the refund is proposed to limit consumers' regret from purchasing early at a higher price, the return option uses the refund to limit consumers' regret from a low realized valuation later.

3.5. Other pricing strategies

Besides the aforementioned pricing strategies, many innovative pricing strategies have been practiced in the industry and/or recently studied in the literature to mitigate the negative impact of strategic consumer behavior on the firm's revenue/profit performance. In this subsection, we will discuss five newly proposed strategies.

The firm could also influence consumers' waiting incentives by intentionally introducing uncertainty to the future price strategic consumers will pay. Cachon and Feldman (2015) propose a *discount-frequently policy* in which the future price is committed but uncertain. In particular, the firm commits to price down the product if its potential demand is lower than a threshold. When there is a search cost for high-valuation consumers to visit the store, they show that under this probabilistic pricing policy, in order to encourage high-valuation consumers to search and visit the store, the firm will provide more frequent and deeper discounts than would be optimal given the realization of demand. Further, they demonstrate that this discount-frequently strategy is optimal and often much better than other deterministic pricing strategies such as fixed pricing strategy and responsive pricing strategy.

Instead of introducing uncertainty to future prices, the firm could randomize the final product strategic consumers will receive. Jerath et al. (2010) study an *opaque selling strategy* under which the firm hides many descriptive attributes of its products so that consumers cannot fully predict the final product among all possible choices. They demonstrate that responsive pricing strategy dominates the opaque selling strategy when consumers' valuations are high or there is little differentiation among all choices; otherwise, the opaque selling strategy prevails. In addition, the increasing probability of high demand may strongly favor the adoption of the opaque selling strategy. However, the effect of opaque selling strategy could be mitigated if strategic consumers exploit these channels through collaboration via social networks. Levina et al. (2015) study three possible collaboration forms: exchange of bid result information, coordinated bidding, and coordinated bidding with risk pooling. They show that these collaborations could significantly increase the benefits for consumers. Further, they argue that these collaborations could expand the market by attracting risk-averse consumers and thus improve the firm's revenue performance.

Chen and Farias (2015) introduce a "restricted sub-martingale" constraint to a continuous time setting under which the firm adopts pre-announced pricing strategy – the *robust dynamic pricing strategy*. Under this constraint, strategic customers will behave myopically and only purchase upon arrival. They show that this robust dynamic pricing strategy is guaranteed to achieve 29% of the optimal revenue under any other optimal dynamic mechanism. In addition, they demonstrate that this robust dynamic pricing is easy to implement as the firm could compute the optimal robust pricing without prior knowledge of consumers' discount factors and monitoring costs.

Without introducing the "restricted sub-martingale" constraint, Aviv and Wei (2016) consider a broad class of mechanisms, early-purchase reward programs, to counteract the negative influence of strategic consumer behavior and identify the optimal program structure. This class of programs is quite general and includes, but is not limited to, strategies such as price matching strategy, the price commitment strategy, responsive pricing strategy, etc. Under a deterministic continuous time model, they obtain a complete analytical characterization of the optimal early-purchase reward program structure, the *surplus-matching early-purchase reward program*, under which it is also optimal for strategic consumers to behave myopically upon arrival. They also extend this optimal surplus-matching program structure to a general modeling framework that consists of market size uncertainty, production costs, mixture of strategic and non-strategic consumers, etc. They demonstrate that the optimal program can be advantageous in settings involving modest-to-high degrees of fashion and high degrees of market size uncertainty, regardless of the percentage of strategic consumers in the market.

One possible risk of being strategic and waiting for possible future discounts is that consumers may need to compete with each other for limited remaining units and may not be guaranteed to obtain the product at the discounted price. To alleviate such risk, Elmaghraby et al. (2009) propose a *reservation regime strategy*: The firms pre-announce both the premium price and the clearance price at the beginning of the season and a consumer could reserve the product for purchase at the clearance price. If the consumer reserves the product and it remains available at the end of the selling season, then this consumer is obligated to purchase it at the clearance price. They show that when there is a single unit of inventory, this additional purchasing/reservation option may not necessarily benefit customers, but could limit the strategic waiting behavior and improve the firm's revenue performance. Under a similar setting with multiple units of inventory available, Osadchiy and Vulcano (2010) show that the reservation option could improve (sometimes more than 12%) the firm's revenue performance when the firm adopts pre-announced pricing strategy together with the reservation option. Surasvadi et al. (2016) propose a contingent price markdown strategy in which reserved units can be claimed only when the number of reservations exceeds a certain threshold (and the firm will immediately discount its price to a pre-announced level) or at the end of the selling season. They show that this contingent price markdown strategy could outperform pre-announced pricing strategy and fixed pricing strategy.

3.6. Additional factors

As discussed in previous subsections, strategic consumer behavior will influence the firm's pricing decisions. Such influence becomes increasingly unpredictable when strategic consumer behavior is integrated with other factors. In this subsection, we will consider the impact of some influential factors, such as waiting pa-

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tience, consumers' regret, product rollover, and competition, on the firm's pricing decisions under strategic consumer behavior.

Consumers' waiting patience could influence the structure and monotonicity of pre-announced pricing strategy. In particular, when consumers exhibit different waiting patience before purchasing or leaving, Besbes and Lobel (2015) show that the firm should restrict its attention to pre-announced cyclic pricing policy. In particular, by focusing on monotonic pricing policies, they demonstrate that it is optimal for the firm to gradually discount its prices and offer two significant discounts – one at the halfway point and the other at the end of the cycle. Further, Su (2007) considers the correlation between the waiting patience and consumers' valuations and shows that when consumers' valuations are negatively correlated with their waiting patience, it is optimal for the firm to pre-announce a monotonically decreasing price scheme, which is consistent with Besbes and Lobel (2015). However, when consumers' valuations are positively correlated with their waiting patience (i.e., high valuation consumers are more patient than low-valuation consumers), the firm should pre-announce an increasing price scheme. In addition, Su (2007) is one of two papers (the second paper is Zhang and Zhang, 2017) that argue strategic consumer behavior may potentially benefit the seller, as low-value consumers' waiting behavior will limit future product availability that could benefit the seller by increasing high-value consumers' willingness-to-pay.

Borgs et al. (2014) consider a multi-period pre-announced pricing problem under a service level guarantee (i.e., the induced demand under pre-announced prices must be no larger than the firm's capacity). They find that due to strategic waiting behavior, price changes may lead to a violation of service level guarantee. Therefore, when strategic consumers become more patient, the firm raises its prices to satisfy the service level guarantee. In addition, the firm will utilize the same prices in multiple periods and limit the number of different prices in its optimal pricing policy. Yet, compared to fixed pricing strategy, this pre-announced pricing strategy continues to prevail.

Consumers' regret could shape the firm's pricing decisions. In particular, regret may arise when a consumer chooses to wait but encounters stockout later (i.e., inaction regret), or when the consumer purchases at the premium price early but realizes that the product is still available at a discounted price or that her valuation turns out to be lower than the premium price (i.e., action regret). Nasiry and Popescu (2012) discuss both action regret and inaction regret and argue that regret can hurt the firm's profitability under pre-announced pricing strategy. Yet, if consumers exhibit heterogeneity in their regret, then the firm could potentially benefit from larger shares of regretful buyers. Further, Nasiry and Popescu (2012) suggests that the negative effect of regret can be mitigated by offering refunds, options, or resale opportunities. Özer and Zheng (2015) also consider consumers' regret and show that pre-announced pricing strategy performs better than the fixed-price strategy when the inaction regret dominates the action regret and consumers value the product sufficiently high.

Pricing decisions also play a significant role in the product launch and rollover strategies. Liang et al. (2014) demonstrate that when there is a large portion of strategic consumers, the firm should not price down the old product upon the new product's launch. Under this situation, a single rollover strategy where the old product is phased out from the market is preferred, especially when the new product's innovation is low. Lobel et al. (2015) also study the product rollover strategy. They show that under the fixed price strategy, the firm can benefit significantly from pre-announcing its technology release and product rollover.

Zhang and Zhang (2017) study the impact of trade-in remanufacturing in a two-period selling horizon. A firm sells a product in the first period and may collect the used products for remanufacturing in the second period through a trade-in program. The authors study how consumer purchasing behavior affects the economic and environmental values of the remanufacturing practice. They show that trade-in remanufacturing helps exploit the forward-looking behavior of strategic consumers, which could be much more significant than the widely recognized revenue-generating and environmental benefits of remanufacturing. In addition, it has been found that the seller may benefit from strategic consumer behavior. This is because strategic consumers take the future trade-in value of a product into account and, therefore, have higher willingness to pay in the first period compared to myopic consumers.

At last, strategic consumer behavior influences the firms' pricing decisions and revenue performance under competition. Levin et al. (2009) present a dynamic pricing model under an oligopolistic setting and show that ignoring strategic behavior can have serious negative impacts on firms' revenues. They also hint that limiting information availability to consumers instead of sharing full information may lead to different equilibrium outcomes from which the firm may potentially benefit. Competition could be either detrimental or beneficial to the firm under strategic consumer behavior. Gilbert and Jonnalagedda (2011) consider a firm pricing durable products and corresponding consumable products (i.e., these durable products need to be used together with consumable products, e.g., iPods and songs, printers and ink). Strategic consumers anticipate the future prices of both durable and consumable products when making purchase decisions for the durables. Under a pre-announced pricing strategy, Gilbert and Jonnalagedda (2011) show that if the firm could commit to shutting down production of its durable products after an initial sale, then the competition from another firm offering consumables of degraded quality could mitigate consumers' fears of being locked in (i.e., lure consumers by charging a lower price for durable products and then extract revenue from charging a higher price for consumables). However, if the firm cannot commit to shutting down the production of its durables, then the competition in the consumables market would be less beneficial.

Parlaktürk (2012) consider vertically differentiated product competition under a duopoly setting. They demonstrate that the loss due to strategic consumer behavior could be smaller under vertically differentiated products than under the single-product benchmark, especially when one product has a significantly lower cost-to-quality ratio. Under a similar setting, Liu and Zhang (2013) show that increasing strategic behavior hurts both firms' profits, but the low-quality firm suffers more than the high-quality firm. Further, they highlight that switching from responsive pricing strategy to fixed pricing strategy, by either firm, could improve profits for both firms.

4. Inventory

Inventory plays a critical role in many operations management settings. A firm's inventory decisions can affect customer purchasing behavior in multiple ways. For example, stocking decisions determine the availability of the products, so they may affect a customer's incentive to visit the store or wait for sales. Also, the sales quantity of a product depends on inventory decisions, which may have certain network effects on customers' perceived utility. In this section, we review the literature that involves firms' inventory decisions under strategic customer behavior. This literature can be divided into two groups. The first group of studies considers a single ordering decision for the firm, while the second allows firms to replenish inventory over time. It is worth noting that in some service operations settings, a firm may make decisions with respect to the capacity rather than the inventory. However, the analysis and

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insights are analogous and therefore we will use inventory and capacity exchangeably in this paper.

4.1. Single order

In operations settings with potential mismatch between supply and demand, stockout is always a risk that customers should not overlook. Therefore, when a strategic customer chooses to wait for better deals, she must evaluate the trade-off between the benefit of lower price and the risk of stockout. Similarly, when there is a setup cost (e.g., time and transportation) for visiting the firm, a customer also needs to gauge the probability of getting the product when paying the setup cost. As a result, a firm may use the stocking decision to influence customers' purchasing behavior. There are a number of papers that examine the role of inventory decisions under strategic customer behavior when there is a single ordering opportunity.

Su and Zhang (2008) are the among the first to introduce strategic customer behavior to the classic newsvendor setting. A newsvendor retailer decides on the price and stocking quantity at the beginning of the selling season. The leftover inventory at the end of the selling season will be salvaged at an exogenous price. Market demand is random and consists of infinitesimal individual customers. Each consumer may either purchase the product in the selling season or wait for the lower salvage price; however, due to uncertain market demand, the product may not still be available after the selling season. Su and Zhang (2008) adopt the rational expectations (RE) equilibrium to characterize the outcome of the game between the customers and the retailer. It has been found that the retailer would charge a lower price and stock a lower quantity, compared to the case with myopic customers. This indicates that a firm may wish to limit its order quantity to contain strategic waiting behavior. The rationale behind this result is intuitive: A lower stock quantity implies a higher stockout probability in the salvage period, which clearly reduces the incentives for customers to wait. A similar finding is reported by Liu and Van Ryzin (2008), who demonstrate that capacity rationing can mitigate strategic waiting behavior using a two-period model with a fixed declining price path. It is worth noting that for the capacity rationing strategy to be optimal, strategic consumers must be perfectly rational and can accurately predict the probability of obtaining a unit in the future; otherwise (e.g., strategic consumers are bounded rational), the capacity rationing strategy may be suboptimal (see Huang and Liu, 2015). Su and Zhang (2008) also show that if the retailer has the commitment power, then it will choose a quantity even lower than that in the RE equilibrium. Thus how to achieve credible quantity commitment becomes an important question. Interestingly, they show that in a decentralized supply chain setting (i.e., when the retailer procures from a supplier), a wholesale price can help the retailer indirectly achieve the commitment power. Hence, a decentralized supply chain under a wholesale price contract may outperform a centralized supply chain without commitment power. Such a finding reveals a new insight that double marginalization can be beneficial to a firm (and a supply chain) when facing strategic customers.

Follow-up studies have extended (Su and Zhang, 2008) to study advance selling or equivalently, preorder strategies. Zhao and Stecke (2010) and Prasad et al. (2011) study when advance selling is beneficial for a newsvendor retailer. A key feature in these papers is that customers have uncertain product valuations in the advance selling period. Depending on problem parameters, the uncertain valuation may either induce customers to preorder or wait, which represents an additional driving force behind customers' purchasing behavior. The authors show in their settings that advance selling is not necessarily beneficial; further, they characterize the conditions under which advance selling is optimal for the newsvendor retailer. Li and Zhang (2013) also consider a preorder setting, but with a focus on the value of advance demand information. By collecting preorders, a firm may update its belief about demand and plan ahead for production and delivery of products. It has been lauded in the operations literature that preorders can provide valuable demand information to facilitate operations planning. In contrast, Li and Zhang (2013) demonstrate that accurate advance demand information may improve product availability, which undermines the firm's ability to charge a high preorder price. Thus accurate demand information does not necessarily help improve a firm's profit under strategic customer behavior. Moreover, they examine the effectiveness of price guarantees in the preorder setting (i.e., compensate preorder customers in case of a price drop); it has been found that accurate demand information may still hurt the firm due to strategic customer behavior. The industry has proposed various innovative advance selling strategies to counteract strategic consumer behavior. For example, Wei and Zhang (2016) study a preorder-contingent production strategy, where the firm's production decision is contingent on preorder quantities. By controlling future product availability, this strategy could effectively mitigate strategic waiting behavior and thus significantly improve the seller's profit performance. In particular, when the market size is deterministic, they illustrate that this preorder-contingent production strategy can completely eliminate strategic waiting behavior and attain the seller's profit performance under the myopic consumer case.

Altug and Aydinliyim (2016) study the impact of return policy on strategic customer behavior. A newsvendor retailer sells a product to customers with uncertain valuations; after purchase, a customer may return the product in case the realized valuation is too low. Clearly, the return policy will affect how many units will be put on the salvage market, which affects the product availability and hence customers' incentives for waiting. The authors develop a model that involves three decisions on pricing, inventory, and refund. They find that under strategic customers, the optimal refund level will be lower than the salvage value (In contrast, the optimal level has been shown to be equal to the salvage value under myopic customers; see Su, 2009). In addition, the retailer might be worse off by allowing returns for strategic customers. A return policy can improve the retailer's profit only when the salvage value is higher than a threshold value.

In many situations, a customer has to incur non-trivial costs even before making a purchase (e.g., time and effort spent on researching the product and traveling to the store). Obviously, such up-front setup costs will be sunk without any return if the product is out of stock. Hence, the willingness of a customer to visit the firm depends on the firm's stocking decision, which determines the availability of the product. There are papers that study how to induce customers to visit a firm using various strategies. Dana and Petruzzi (2001) endogenize the relationship between inventory level and demand (i.e., high inventory induces more demand due to higher availability) for the classic newsvendor model. They find that under such a relationship, firms will stock more and provide a higher fill rate. Su and Zhang (2009) considers a newsvendor retailer selling to strategic customers with a search cost. The retailer determines a price and an unobservable stocking quantity; the customers decide whether to visit the retailer or not. When making the visit decision, the customer needs to evaluate the probability of product availability. The retailer may use two strategies to induce a customer visit and improve profits. First, the retailer may offer availability guarantees (e.g., compensate the customer if there is a stockout); second, the retailer may commit to a certain stocking quantity (e.g., reveal the stocking information through a credible party). They show that the retailer can achieve the optimal profit and at the same time maximize the social welfare by using a combination of these two strategies.

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Cachon and Feldman (2015) propose a new strategy to deal with strategic customers who are sensitive to the search cost. A customer is more willing to incur the search cost when the anticipated price is low and/or the likelihood of availability is high. Thus, a firm may either overstock (to signal availability) or offer frequent price discounts (to strengthen the belief of low price). It has been found that the frequent discount strategy is optimal for the firm and thus works better than the overstock strategy. Although the literature generally suggests the firm should limit markdowns and purchase ample capacity in such problem settings, the authors demonstrate that a strategy that uses frequent discounts under moderate capacity could be optimal.

A customer's consumption utility from a product often depends on the number of other customers who also purchase the product. Depending on the nature of the product, such a network effect can be either positive (e.g., for products that enjoy complementary effects) or negative (e.g., for products that emphasize exclusivity). It is clear that the sales quantity of a product hinges upon how many products a firm releases in the market. Thus it is important to study the impact of network effect on firms' stocking or production strategies. Tereyağoğlu and Veeraraghavan (2012) consider a retailer's problem when selling to conspicuous consumers. The retailer can set price and production quantity to serve an uncertain market. Consumers are conspicuous and thus prefer exclusivity of the product. The authors study how to achieve the scarcity effect for such a market and demonstrate that the effectiveness of the scarcity strategy depends on the variability of the market demand. They also show that to credibly commit to the scarcity strategy, the firm may purposely choose expensive sourcing options (e.g., sourcing from expensive locations and using expensive raw materials). With the rapid developments of social media, the network effect will become more significant; therefore, analyzing its impact on firms' operations strategies represents a promising research direction.

4.2. Multiple orders

Although models with single ordering opportunity yield useful insights into problems under strategic customer behavior, it is not uncommon that a firm can replenish inventory over time. In this subsection we proceed to review studies that consider multiple ordering opportunities when selling to strategic customers. With more than one ordering opportunity, a firm is able to dynamically adjust the stocking decisions; at the same time, it allows customers to form beliefs based on the market outcome over time. These features may lead to new insights compared to the single-order model settings.

Several papers investigate the value of quick response when selling to strategic customers. Quick response, a commonly adopted practice, allows the firm to place two orders to satisfy highly unpredictable market demand: The first order is placed before the selling season starts, and the second order after observing sales at the beginning of the selling season. This has been widely recognized as an effective tool for matching supply with demand in the traditional supply chain management literature. Cachon and Swinney (2009) re-examine the value of quick response in the presence of strategic customers. Specifically, a retailer sells a product in a single season with random demand. The retailer first sets the price at the beginning of the selling season and then marks down the leftover inventory at the end of the season; moreover, under quick response, it may place two orders, before and after the start of the selling season, respectively. The authors introduce three types of customers into such a setting: myopic customers who always purchase at the initial price, bargain customers who only purchase if the markdown price is low enough, and finally, strategic customers who optimize the timing of purchase to maximize the expected surplus. It has been shown that quick response could be much more valuable when there are strategic customers. The reason is that quick response can reduce the probability of a massive inventory for markdown, which discourages the incentives for customers to wait for lower price. Therefore, Cachon and Swinney (2009) reveal a new insight that in addition to helping match supply with demand, quick response is a highly effective tool for containing strategic customer behavior. Cachon and Swinney (2011) study a fast fashion retailer's problem by combining quick response with enhanced product design. Note that quick response allows the firm to minimize the lead time for procurement, while enhanced design allows the firm to capture the latest consumer trend. They find that similar to quick response, enhanced product design also helps mitigate strategic customer behavior. This is because enhanced design will offer a more valuable product to customers and make them less willing to wait and bear the stockout risk. It has also be found that, although these two strategies can be either complements or substitute, the complementary effect tends to dominate. That is, combining quick response with enhanced design would generally lead to higher profits and more effectively deal with strategic waiting behavior. Swinney (2011) continues to explore the value of quick response by incorporating uncertain customer valuations. Specifically, the customers have uncertain, heterogeneous valuations for the product; the firm can either commit to a single production run or commit to the quick response strategy. In contrast to Cachon and Swinney (2009), it is shown that the value of quick response is generally lower under strategic customers than under myopic customers. This finding indicates that uncertain customer valuation is an important driving force that firms should not overlook when devising strategy under strategic customers.

Dynamic models allow the firm and customers to repeatedly interact with each other. A couple of studies look into how firms can use capacity rationing to shape customers' belief about product availability. Liu and Van Ryzin (2008) study firms' capacity rationing strategy when customers can learn through repeated purchases. Although customers cannot observe the firm's capacity decision, they can update their belief about availability based on the market outcomes in previous periods. They find that two market equilibria may arise in their model: a rationing equilibrium (where the firm charges a high price and only serves the top portion of the market) and a low-price equilibrium (where the firm charge a low price and serve the whole market). The actual equilibrium outcome depends on the initial expectation of product availability. Their result helps explain why some firms can be stuck with low-price strategy due to unfavorable customer initial expectations even though it is not the most profitable strategy. Courty and Nasiry (2016) suggest that the firm could also produce less to intentionally undersupply consumers (i.e., buying frenzy), when consumers are sufficiently uncertain about their valuations and discount their future surplus to a certain extent. They argue that such buying frenzy could be beneficial if the firm could not commit to future prices. Liu and Shum (2013) extend this line of research by considering customer disappointment aversion. Using a two-period model, they find that without disappointment aversion, the firm will use a uniform pricing policy without rationing; however, under disappointment aversion, rationing might be used to improve the firm's profit. In other words, disappointment aversion could be another reason for firms to use capacity rationing.

Agrawal et al. (2015) develop a multi-period model to study the so-called planned obsolescence strategy where the firm determines the durability of the product. Intuitively, a low durability allows the firm to sell more products and enjoy higher profit. However, many firms do not follow such a strategy in practice. The authors characterize the conditions under which the firm may adopt a high-durability low-volume strategy. In particular, they show

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that high durability may induce consumers to pay a higher price due to higher resale value; this is especially the case when customers value the exclusivity of the product. Hu et al. (2015) studies a joint inventory and markdown management problem under strategic customer behavior. A firm sells a perishable good in a multi-period horizon; in each period, the firm sets the markdown price for leftover inventory from the previous period and also determines the order quantity for regular sales. This is similar to Agrawal et al. (2015) in that it also focuses on obsolescence management. Hu et al. (2015) find that the firm should either markdown all leftover inventory or dispose of all of them (i.e., a partial markdown is not optimal). In addition, there is a threshold beyond which the leftover inventory should be marked down. Their research provides structural insights into such a complicated pricing and inventory management problem.

5. Information

Rational customers act based on their information about the product and market. Thus firms can use the lever of information to influence customer behavior. In this section, we consider how firms can deal with strategic customer behavior by managing information. To maintain focus, we only review studies involving firms' decisions that directly affect the information available to customers. In all the studies reviewed below, research results have useful implications on how firms should manage information when selling to strategic customers.

Stocking level is clearly important information from customers' perspective because it determines product scarcity and availability. Revealing inventory information is essentially equivalent to quantity commitment. The literature has shown that credibly conveying inventory information to customers will help improve firm profit when customers care about the stockout risk (see, e.g., Su and Zhang, 2008,2009). Allon et al. (2011) study the provision of real-time unverifiable inventory information to customers in a retail setting. They consider a two-period selling horizon with declining retail prices. The initial inventory is exogenously given and not observable to customers. The firm is allowed to use any information provision strategy to communicate with customers. The authors characterize the equilibrium outcome of the communication game between the firm and customers. It has been found that with homogeneous customers, the equilibrium language by the firm would carry no information. That is, in such a case the firm is unable to share credible information to influence customer behavior. However, when customers exhibit heterogeneous characteristics, they show the firm is capable of influencing customer behavior via sharing availability information under certain conditions. Yin et al. (2009) study an innovative approach to information release through inventory display. Two strategies have been considered: display all (DA), where all available inventory is shown to customers, or display one (DO), where only one unit is put on display at a time. Clearly, the two display formats send different information to customers when making their purchase decisions. Assuming a fixed price path, the authors examine the impact of different display strategies on firm profit. They find that DO can create a sense of shortage risk and thus would work better than the DA format; nevertheless, even DO is not effective in eliminating strategic waiting behavior. Furthermore, it has been found that if a retailer wants to shift from DA to DO, it is not necessary to significantly alter the inventory level – an appropriate price modification with the original inventory level would be sufficient.

There are papers that consider managing information about product characteristics. Jerath et al. (2010) study the benefit of hiding product information in a revenue management setting. Last-minute sales is commonly used in many service industries (e.g., airline and hotel) to dispose of unsold capacity. Although such a practice helps firms reap additional revenue, it may also train strategic customers to purposely wait for lower prices. To mitigate the strategic waiting behavior, firms may use an opaque intermediary for last-minute sales, which hides the information about the actual provider of the service. The authors find that opaque selling is preferred over direct selling when customer valuations are relatively low or the differentiation among competing service providers is relatively large. In addition, opaque selling becomes more attractive when the probability of high demand increases. Chu and Zhang (2011) investigate a retailer's information control strategy in advance selling. The retailer takes preorders from customers in the advance selling period and can decide how much information about the product to share with the customers. They show that the firm's optimal pricing strategy depends on the amount of information available to customers. Specifically, varying the amount of information may cause a dramatic change in the preorder demand under optimal pricing. It has also been found that in the optimal information strategy, the retailer should either release no information or release partial information, but never release all information. Yu et al. (2015) studies a dynamic pricing problem under the presence of consumer-generated quality information. Consumers who have purchased the product may share their opinions with other potential buyers; however, the informativeness of the product information depends on the volume of sales. Thus, the seller can control the quality information by controlling the initial sales. It has been shown that the firm might be worse off due to consumer-generated quality information; even when the firm can benefit from the quality information, it may prefer less accurate information. Interestingly, in such a model setting, the consumers might be worse off under the presence of consumer-generated information, a result that contrasts with common wisdom that word-of-mouth information will help consumers.

A few studies consider the value of information for the seller in various settings. Mersereau and Zhang (2012) study a markdown pricing problem with an unknown fraction of strategic customers. Specifically, a firm sells a product in a two-period horizon and charges different prices over time. The market consists of both myopic and strategic customers, but the exact composition of the two types of customers is unknown to the firm. The authors demonstrate that a robust pricing policy performs well even without the knowledge of the fraction of strategic customers. The finding indicates that in such a model setting, the need to recognize strategic behavior is not as strong as one may expect.

Huang and Van Mieghem (2013) study the value of demand information that can be collected by click tracking. They adopt a newsvendor model setting similar to that in Su and Zhang (2009), except that the customers can choose to visit (and click on) the website or not. When they click on the website, the seller can collect more information about market demand. It has been shown that there exists an equilibrium in which all customers are willing to click and provide advance demand information to the firm. In addition, the strategic customer behavior can be beneficial in the context of click tracking, and click tracking can be advantageous both to the firm and to customers.

A recent paper by Shum et al. (2016) examines the impact of uncertain cost reduction when selling to strategic customers. It is not uncommon that a product experiences cost reduction during the life cycle; however, the magnitude of cost reduction is uncertain. How does this uncertainty affect strategic customer behavior and firm profit? Shum et al. (2016) show that the firm's profit would be higher if the future cost is more uncertain; however, a more significant cost reduction does not necessarily benefit the firm. The result has useful implications for firm's pricing strategy as well as cost reduction investment decisions. In a similar vein, Mantin and Rubin (2016) investigate the impact of future price in-

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formation on customer behavior and firm profit. By using a dataset from the airline industry, they empirically examine how the provision of future price information affects transaction prices. There is a significant price reduction effect as future price information becomes available to customers, which indicates that helping customers predict future price would aggravate strategic waiting behavior. This cautions firms to be careful in providing information and setting prices when facing strategic customers.

6. Conclusion and future research

In this article, we review research papers that have recently emerged in the Management Science and Operations Management discipline and focus on the mechanisms and strategies to counteract the adverse influence of strategic consumer behavior. In particular, we categorize these mechanisms and strategies into three classes: Pricing, Inventory, and Information. In each of these three classes, the literature has been expanded extensively in the past decade, and an increasing number of innovative policies and strategies has been proposed to mitigate the adverse effect of strategic waiting behavior. We believe that modeling strategic consumer behavior will continue to be a fruitful research arena, as existing research has been repetitively affirming the importance of endogenizing such behavior in the firm's decision-making process. Although we have seen a growing number of research papers that are devoted to this area, there are still many new directions worth further investigation.

In the big data era, individual-level data have been accumulated with extraordinary speed, and the growing availability of customer-specific data, including social media, demographics, geographic, browsing/shopping history, etc., provides both firms and consumers with unprecedented opportunities to tailor decisions to their own needs. One direct, and somewhat unfavorable, impact of this data is that it encourages strategic waiting behavior by equipping consumers with accurate historical pricing information. The immediate question is: How do consumers monitor price changes and/or predict future price trajectory? There are research papers that have started developing heuristics to model how strategic consumers make decisions based on available past pricing information (e.g., Wu et al., 2015). We believe it will be a promising and critical direction to understand this question, as to design better operational decisions, the firm must first understand the long-term impact of its pricing decisions. Besides pricing information, consumers receive, both actively and passively, information from their peers and social networks. Accordingly, how information spread among strategic consumers, how social networks change strategic consumers' valuations and purchasing decisions, and accordingly how firms can influence these processes will be uncharted but interesting topics to explore.

Big data could fundamentally changes firms' decision-marking processes by enabling them to predict consumers' responses and to propose innovative operational strategies based on the consumers' contextual information. Customers' data is typically high-dimensional, and therefore the question of how to select the most significant covariates and what predictive model to adopt to predict consumers' purchasing timing decisions will be challenging. Novel models and algorithms have been proposed in statistics and computer science communities (e.g., Tibshirani, 1996 and Fan and Li, 2001), and it will be a timely research topic to better understand and predict strategic consumers' responses to different operational decisions via this lens. In addition, identifying dynamic strategies based on consumers' contextual information has been an active research area in our community (e.g., Bastani and Bayati, 2015, Cohen et al., 2016, and Javanmard and Nazerzadeh, 2016). Yet, to the authors' best knowledge, currently in this line of research, papers that integrate strategic consumer considerations are absent. Therefore, research that implicitly models strategic consumers' responses will enable the firm to design better operational strategies and generate more useful and practical insights.

Lastly, we observe that recently, there is a growing interest in data-based empirical and experimental studies (e.g., Li et al., 2014 and Osadchiy and Bendoly, 2015). The increasing availability of data enables scholars to answer questions that are difficult to calibrate through theoretical research. For example, how prevalent is strategic consumer behavior in practice and in different industries? Is it possible to quantify the effect of strategic customer behavior on the firm's profit and financial performance? Can we empirically or experimentally verify the existing findings from theoretical research? The answers to these questions could significantly improve the relevance of our theories by connecting them to real practice and help generate new theories to better explain the real-world observations. We, therefore, expect that empirical and experimental studies will be an important part of future strategic consumer behavior research.

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