Choosing to Be Strategic: Implications of the Endogenous Adoption of Forward-Looking Purchasing Behavior on Multiperiod Pricing

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Abstract

Pricing over multiple periods under forward-looking, strategic consumer purchasing behavior has received significant recent research attention; however, whether consumers actually benefit from this behavior and would voluntarily choose to be strategic has not been previously considered. We explore this question, and show that many consumers have lower surplus if they are strategic than if they are myopic. We then develop a model in which consumers choose to become strategic by exerting costly effort, and show three key implications of this choice. First, it is possible to increase firm profit, consumer welfare, and social welfare simultaneously by increasing the cost of strategic behavior, suggesting firms can, essentially, force consumers to be myopic and make all parties better off; this helps explain how firms that do the most to make strategic behavior difficult are able to attract more demand and be successful in the marketplace. Second, efforts to mitigate strategic consumer waiting by committing to future prices instead of pricing dynamically may decrease the cost of strategic behavior and backfire, encouraging more consumers to be strategic; hence, in contrast to most previous research, price commitment may yield lower profit than dynamic pricing if consumers can choose to be strategic. And third, considering the consumer choice to be strategic can have a significant qualitative impact on firm and consumer decisions.

Key words: strategic consumer behavior, dynamic pricing, price commitment, revenue management

1 Introduction

Multiperiod pricing is a central concern of firms selling physical goods, particularly those that are durable in nature. In recent years, however, an increasingly large proportion of the consumer population has become aware of and responsive to the inter-temporal pricing strategies of firms, allowing them to anticipate price changes and optimally time their purchases (Li et al. 2014). The term “strategic consumer behavior” has become synonymous with this type of rational, forward-looking purchasing behavior (Su & Zhang 2008; Cachon & Swinney 2009), and understanding the extent of and optimal response to such strategic consumer behavior has become a topic of great interest to both practitioners and researchers. In the academic literature, while most work on the pricing and inventory management of physical goods had previously assumed

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consumers were not strategic, a new stream of research has rapidly developed to analyze the impact of strategic consumer behavior on a firm’s optimal decisions along numerous dimensions, including pricing, inventory, and supply chain management (see, e.g., Aviv & Pazgal 2008; Zhang & Cooper 2008; Yin et al. 2009; Jerath et al. 2010; Levin et al. 2010; Lai et al. 2010; Osadchiy & Vulcano 2010; Cachon & Swinney 2011; Mersereau & Zhang 2012; Cachon & Feldman 2015b; Zhang & Zhang 2015; Aviv et al. 2015; and many others).

Research into this phenomenon typically classifies consumers into one of two types based on the decision rule they use when purchasing a product. Consumers are said to follow a **strategic purchasing rule** if they consider the future when making their purchasing decisions today. That is, for a product sold over two periods, a consumer follows a strategic purchasing rule if she arrives in period 1, considers her utility from delaying her purchase to period 2, and chooses to purchase in the period that maximizes her utility. Conversely, a consumer follows a **myopic purchasing rule** if she does not consider period 2 when making her purchasing decision in period 1; consequently, she purchases in period 1 if and only if her utility from a purchase is non-negative. Consumers following these rules are frequently referred to as “strategic” and “myopic” consumers, respectively, in the literature. A consumer employing a strategic purchasing rule is distinct from, but related to, the phenomenon of **strategic waiting**, which occurs when a consumer intentionally decides to delay a purchase in order to obtain the product at a lower price. A consumer can only strategically wait if she follows a strategic purchasing rule; however, not all consumers who follow a strategic purchasing rule, in equilibrium, may choose to strategically wait.

Given this distinction, existing research into strategic consumer behavior is primarily divided into theoretical studies concerning methods to reduce strategic waiting (Su & Zhang 2008; Aviv & Pazgal 2008; Cachon & Swinney 2009; Yin et al. 2009) and empirical studies estimating the prevalence of strategic waiting (Osadchiy & Bendoly 2010; Soysal & Krishnamurthi 2012; Li et al. 2014). In both cases, it is generally assumed that consumers (or some fraction of consumers) exogenously employ a strategic purchasing rule: a particular customer is either strategic or myopic, and the extent of strategic behavior in the population is specified as a model primitive. As such, previous work has mostly ignored two key questions regarding strategic consumer behavior: first, whether consumers in fact benefit from strategic behavior, and second, whether consumers would, if given the choice, decide to be strategic by adopting a strategic purchasing rule. These are deceptively simple questions: fixing the firm’s actions—in particular its prices—it is clearly true that an individual consumer can do no worse by considering the opportunity to purchase in future periods in addition to purchasing in the period in which she arrives. However, once all consumers consider the

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1While the term “strategic consumer” can also describe other types of behaviors, e.g., consumers strategizing over when to visit a congested service system (Lariviere & Van Mieghem 2004), in this paper we use the term to exclusively refer to forward-looking utility-maximizing consumers who optimally time their purchase when prices vary over time.
opportunity to purchase in future periods and optimally time their purchases, and once the firm responds optimally to this behavior by adjusting its prices, it is no longer obvious that strategic purchasing behavior will result in an increase in individual consumer (or, indeed, social) welfare.

These are important questions to answer for at least three reasons. First, the implicit assumption in both the popular press and in many earlier works has been that the pricing game between the firm and consumers is zero-sum in nature (Su 2007), and as such strategic consumer behavior represents a wealth transfer from the firm to consumers that unambiguously benefits the customer population. In other words, consumers are typically encouraged to be strategic, as this is in their own interests and, it would seem, is only detrimental to the firm. However, if conditions exist under which strategic behavior either harms consumers or society, then this type of consumer behavior is cast in a new light; strategic behavior by consumers would not merely lead to a wealth transfer in a zero-sum game, but rather it would be an actively destructive force that, while possibly individually rational for consumers, leads to an equilibrium in which society is worse off. Second, in practice, consumers are unlikely to be exogenously endowed with a particular type of behavior. Strategic behavior requires consumers to exert effort and incur some associated costs, e.g., due to the hassle cost of finding the optimal time of purchase and the effort required to implement an optimal purchasing strategy by taking actions such as monitoring prices, identifying the exact time of a price reduction, and making return visits to a physical store or website. Hence, a rational consumer, aware of the net value of engaging in strategic behavior, would rationally choose whether to employ a strategic purchasing rule or a myopic purchasing rule. Given this, knowing whether—and which—consumers benefit from strategic behavior can help to illuminate conditions under which strategic behavior is and is not likely to be adopted by consumers, and help firms understand how to respond via their pricing policy. Third, as the magnitude of the effort costs associated with strategic behavior are likely related to the selling strategy employed by the firm, it is also probable that the population of consumers who choose to be strategic will differ under different selling strategies, which in turn may affect how beneficial different strategies are for the firm.

In this work, we explore precisely these issues. To accomplish this, we analyze a model of a firm selling a single product over two periods (§3). Consumers have heterogeneous valuations, and hence the firm has an incentive to set different prices in each period and segment the market. We first examine a model of exogenously specified behavior in which consumers are either myopic or strategic (i.e., they exogenously follow a myopic purchasing rule or a strategic purchasing rule), and we determine the firm’s optimal prices when they are set dynamically (i.e., established at the start of each period to maximize profit-to-go). Using this classical framework as a starting point, we examine the impact of strategic consumer behavior on all stakeholders in the system: the firm, and, in contrast to previous work, consumers and society (§4). We find that all consumers do not benefit from being strategic: consumers with low valuations are indifferent
to strategic behavior, consumers with moderate valuations are worse off under strategic behavior, and only consumers with high valuations are better off under strategic behavior. Moreover, social welfare is always higher under myopic consumer behavior—hence, the game between the firm and consumers is not zero-sum, and strategic consumer behavior is detrimental to society as a whole.

Motivated by this finding, in §5 we develop a new model of endogenous consumer purchasing behavior in which consumers choose between being “myopic” and being “strategic.” Specifically, we posit that all consumers are inherently rational, but they may choose whether to adopt a myopic purchasing rule or a strategic purchasing rule, taking into account the expected net value of the latter, which includes both a benefit (i.e., the incremental increase in utility from optimizing the purchase time) and a cost (i.e., the effort required to find and implement the optimal purchase strategy). We determine precisely which consumers do—and do not—choose to be strategic, and show that the firm’s optimal dynamic pricing policy differs qualitatively under endogenous behavior from the optimal policy under exogenous behavior: the optimal prices are not monotonic in the consumer cost of strategic behavior, and it is possible for the firm’s optimal prices in each period to be strictly lower under endogenous behavior than under myopic behavior, something that never happens if consumers are assumed to be exogenously strategic.

Our results have several further implications for firms, which we discuss in detail in §6. First, while making strategic behavior difficult for consumers seems like an effective strategy for firms selling to a captive customer population, it is unclear why this would be as valuable for firms selling to consumers with outside options, such as purchasing from competitors or reducing or forgoing consumption. In other words, if strategic behavior is good for consumers, why would consumers continue to shop at firms that make it difficult to be strategic? Using our endogenous behavior model, we show that by increasing the cost of strategic behavior, the firm can not only improve profit, it can also increase consumer and social welfare. In other words, the firm, by forcing consumers to be myopic and thereby limiting consumer purchasing options, may actually make itself, consumers, and society better off. Thus, our model suggests that such firms can be successful precisely because they make strategic behavior difficult, since consumer and social welfare are also maximized when the cost of being strategic is high. Second, we show that, in contrast to conventional wisdom, selling strategies designed to mitigate strategic waiting (e.g., committing to keep prices high) may in fact decrease firm profit if they also impact the cost of being strategic. Therefore, when thinking about whether to implement a particular selling strategy, not only is it important to account for strategic behavior, it is also important to consider the costs associated with becoming strategic and the consumer choice to adopt a strategic purchasing rule, as this may have a significant effect on profit. Taken in sum, our results illustrate the importance of both considering the impact of strategic behavior on consumers and accounting for the consumer decision to become strategic.
2 Literature Review

While anecdotal evidence of strategic consumer behavior is pervasive, rigorous empirical evidence that consumers exhibit strategic behavior is limited (due in part to the econometric challenges associated with this problem) but growing. Li et al. (2014) use data from the travel industry to determine that 5% to 45% of consumers are forward-looking and strategically time their purchases. Nair (2007) and Soysal & Krishnamurthi (2012) similarly demonstrate that forward-looking behavior has a significant impact on firm profits using data from the video game and apparel industries, respectively. In a laboratory context, Osadchiy & Bendoly (2010) and Mak et al. (2014) determine that a significant fraction of subjects are strategic.

Supported by the increasing empirical evidence of this type of behavior, the literature on strategic consumers is growing rapidly, and forward-looking consumer behavior has received significant theoretical attention in the economics, marketing, and operations literatures over the last decade. Motivated by the conjecture of Coase (1972) that a monopolist attempting to “price skim” over time would be unable to prevent consumers from strategically waiting for the lowest price, Stokey (1981), Bulow (1982), and Besanko & Winston (1990) were among the first to model this dynamic as one in which consumers are forward-looking and optimally choose their purchase time. More recently, Bergemann & Välimäki (2006); Su (2007); Aviv & Pazgal (2008); Levin et al. (2010); Mersereau & Zhang (2012); Ovchinnikov & Milner (2012); Aviv & Wei (2015); Aviv et al. (2015), and others have analyzed the multiperiod pricing problem under strategic consumer behavior in a variety of richer contexts. This work was later extended to consider the impact of strategic behavior on firm decisions beyond pricing, such as inventory (Liu & van Ryzin 2008), supply chain design (Cachon & Swinney 2009), advance selling (Prasad et al. 2011; Wei & Zhang 2015; Cachon & Feldman 2015a), product variety (Parlaktürk 2012), posterior price matching policies (Lai et al. 2010; Surasvadi & Vulcano 2013), assortment rotation (Bernstein & Martínez-de Albéniz 2014), and customer voting systems (Marinesi & Girotra 2013); we refer readers to Netessine & Tang (2009) for an extensive review.

Our work differs from these earlier models in two key ways. First, when consumer behavior is exogenously specified, we consider the impact of strategic behavior on consumers themselves and society (the firm and consumers) as a whole, as opposed to just the firm. This allows us to determine which consumers benefit from strategic behavior and which do not, and moreover, whether society is better off when consumers are strategic. Second, in all earlier work on strategic consumer behavior that we are aware of, both empirical and theoretical, an implicit assumption is that consumers are exogenously either myopic or strategic. That is, the question of how consumers came to be strategic is not considered. In that sense, earlier work can be thought of as endogenizing when consumers wish to purchase, but not whether they are strategic in the first place. This is an important question, because while the inter-temporal consumer purchasing problem has
received a great deal of attention in economics, marketing, and operations management, whether consumers benefit from engaging in strategic behavior will directly impact the results in each of these literatures. This is a key focus of our work, and we show that endogenizing the decision to be strategic can have a significant impact on the value (to the firm, consumers, and society) of the firm’s pricing and selling strategy.

3 Model

We study a firm that sells a single product over a finite selling season. The selling season consists of two successive periods, labeled 1 and 2. The firm can charge different prices in each period: the price is $p_1$ in period 1 and $p_2$ in period 2. The firm’s marginal and fixed costs are normalized to zero. The firm’s objective is to maximize its total profit, $\pi$, which consists of the undiscounted sum of the profit in each period. For the majority of our analysis, we assume that the firm prices dynamically, i.e., sets the price in each period to maximize profit-to-go; in §6, we also discuss implications of a price commitment strategy, in which the firm credibly commits at the start of the season to prices over the entire selling horizon.

At the beginning of period 1, a deterministic mass of consumers arrives. The size of this population is normalized to one. Each consumer purchases at most once, and values the item at $v \geq 0$. Consumers have heterogeneous valuations with distribution $G(x)$, a continuous and differentiable function, and density $g(x)$. All consumers identically discount period 2 surplus by $\delta \in (0,1)$ (Cachon & Swinney 2011). Thus, a consumer with valuation $v$ who purchases in period 1 receives utility $u_1(v) = v - p_1$, a consumer who purchases in period 2 receives utility $u_2(v) = \delta(v - p_2)$, and a consumer who does not purchase receives zero utility. Note that we assume that the firm does not discount period 2 profit while consumers do discount period 2 surplus, i.e., the firm is more patient than consumers; this assumption is frequently made in the literature (Landsberger & Meilijson 1985; Cachon & Swinney 2011) and may be relaxed without significantly impacting the results.

As noted in the introduction, we consider two broad models of consumer behavior. In the first, consumer behavior is exogenously specified, and all consumers are either myopic or strategic. In the second, consumers are intrinsically myopic but can endogenously choose to become strategic by exerting effort and paying a cost. We defer discussion on the latter case to §5; here, we discuss the exogenous behavior model. As previously indicated, we say that a consumer follows a myopic purchasing rule if she purchases whenever she observes a price lower than her valuation. Alternatively, a consumer follows a strategic purchasing rule if she anticipates the possibility of purchasing in period 2, and rationally decides whether to purchase the product in period 1 or delay until period 2. We use the terms “myopic consumer” and “strategic consumer” as short-hand to denote consumers that follow a myopic purchasing rule or a strategic purchasing rule,
respectively. In addition, we say that a consumer *strategically waits* or *delays a purchase* if her utility from a purchase in period 1 is non-negative, but she delays her purchase to period 2 to obtain the product at a lower price. Given these definitions, myopic consumers purchase in period 1 if \( u_1(v) \geq 0 \), while strategic consumers purchase in period 1 if \( u_1(v) \geq \max(u_2(v), 0) \) (note that we assume consumers that are indifferent between periods purchase in period 1).

We denote equilibrium values under myopic behavior by the superscript \( m \), and equilibrium values under strategic behavior by the superscript \( s \). When analyzing the impact of strategic behavior on consumers and society, we will consider several metrics, summarized in Table 1, each defined for scenario \( j \in \{m, s\} \). Most of these metrics are fairly standard definitions. For instance, \( u^j(v) \) is the equilibrium surplus to a consumer with valuation \( v \), \( CS^j = \int u^j(v)g(v)dv \) is total consumer surplus, and \( SW^j = CS^j + \pi^j \) is total social welfare, each for scenario \( j \in \{m, s\} \). Several metrics require further explanation. First, we define the value of strategic behavior \( V(v) \) to an individual consumer to be the difference between her optimal utility if she (and all other consumers) exhibits strategic behavior and her utility if she (and all other consumers) exhibits myopic behavior, given that the firm is aware of the type of consumer behavior and prices optimally, i.e., \( V(v) = u^s(v) - u^m(v) \). The value of strategic behavior to the entire consumer population (\( CV \)) and to the firm (\( FV \)) are defined similarly, using total consumer surplus and firm profit, respectively, rather than individual consumer surplus, i.e., \( CV = CS^s - CS^m \) and \( FV = \pi^s - \pi^m \). Lastly, we say that the value of strategic behavior to society \( SV \) is the difference between social welfare (total consumer surplus plus firm profit) when all consumers are strategic and when all consumers are myopic, i.e., \( SV = SW^s - SW^m \).

### 4 Exogenous Behavior: The Value of Strategic Behavior

We first analyze the value of strategic behavior to consumers and to society under exogenous behavior. That is, we calculate the difference between consumers’ utility if they all (exogenously) behave strategically, and their utility if they all (exogenously) behave myopically. Exogenous behavior is the standard assumption...
in the existing pricing literature on forward-looking behavior, and as such serves as an important baseline for us to understand how strategic behavior impacts consumers and society. The sequence of events is as follows. At the start of period 1, the firm chooses the period 1 price, $p_1$. Then, all consumers arrive, observe $p_1$, and choose whether to purchase in period 1 or wait for period 2. Next, at the start of period 2, the firm chooses the period 2 price, $p_2$. Lastly, all remaining consumers observe $p_2$ and choose whether to purchase or not.

We begin by formulating the firm’s optimization problem with myopic consumers. Since myopic consumers purchase in period 1 if their valuations exceed the selling price, period 1 demand is $1 - G(p_1)$ and period 1 profit is $(1 - G(p_1))p_1$. Period 2 demand is thus $G(p_1) - G(p_2)$, and period 2 profit is $(G(p_1) - G(p_2))p_2$. The firm sets $p_1$ at the start of the horizon and $p_2$ dynamically in period 2 to maximize profit-to-go. Hence, the firm’s period 1 optimization problem is:

$$\max_{p_1, p_2} (1 - G(p_1))p_1 + (G(p_1) - G(p_2))p_2$$

s.t. $p_2 \in \arg\max_x (G(p_1) - G(x))x$ (1)

Let $p_{1m}^n$ and $p_{2m}^n$ be the optimal prices that result from this optimization problem. If consumers’ valuations follow a uniform distribution on $(0, 1)$, it is straightforward to find that the optimal prices under myopic behavior are $p_{1m}^n = \frac{2}{3}$ and $p_{2m}^n = \frac{1}{3}$.

When consumers are strategic, the firm and consumers play a game: the firm chooses prices and consumers choose when (and whether) to purchase the product. We seek the subgame perfect Nash equilibrium (SPNE) to this game. The optimal actions of the firm and consumers in period 2 may be solved immediately; the first significant step in deriving the equilibrium is thus to establish the optimal action of consumers in period 1, after having observed a posted period 1 price from the firm. Lemma 1 illustrates that strategic consumers follow a threshold purchasing rule, i.e., for any $p_1$ chosen by the firm, there exists some $\bar{v}$ such that consumers purchase in period 1 if and only if $v \geq \bar{v}$.

**Lemma 1.** There exists a unique threshold $\bar{v}$ such that all strategic consumers with valuation $v \geq \bar{v}$ purchase in the first period and consumers with valuation $v < \bar{v}$ delay purchasing until period 2.

**Proof.** All proofs appear in the appendix. \hfill \Box

We thus refer to a consumer with valuation $\bar{v}$ as the “threshold consumer.” (Note that the analogous threshold consumer under myopic behavior has valuation $p_1$.) Given this, the firm’s period 1 problem can be written as follows:
\[
\max_{p_1, p_2} \left( 1 - G(\tilde{v}) \right) p_1 + (G(\tilde{v}) - G(p_2)) p_2
\]

\[
s.t. \quad \tilde{v} = \{ \min \hat{v}, \text{ s.t. } \hat{v} - p_1 \geq \delta(\hat{v} - p_2) \}^+
\]

\[
p_2 \in \arg \max_x (G(\overline{v}) - G(x)) x
\]  

(2)

Let \(p_1^s\) and \(p_2^s\) be the equilibrium prices and let \(\overline{v}^s\) be the equilibrium valuation of the threshold consumer under strategic consumer behavior. These equilibrium values critically depend on \(\delta\). (For example, observe that when \(\delta = 0\), strategic consumers do not have an incentive to delay their purchases and therefore behave in the same way as myopic consumers.) Therefore, we analyze the equilibrium as a function of \(\delta\). To accomplish this, we define the partial order on \(\mathbb{R}^n\) be the componentwise order. More precisely, for some \(x, y \in \mathbb{R}^n\), we say \(x \preceq y\) if and only if \(x_i \leq y_i\) for all \(i \in \{1, \ldots, n\}\). We also define \(x \wedge y = (\min(x_1, y_1), \ldots, \min(x_n, y_n))\) and \(x \vee y = (\max(x_1, y_1), \ldots, \max(x_n, y_n))\) as the meet and joint of two elements of \(\mathbb{R}^n\). A set is a lattice if it is closed under meet and joint. Lastly, we say that set \(A\) is greater than set \(B\) with respect to the strong set order (denoted by \(A \succeq B\)) if for any \(x \in A\) and \(y \in B\), we have \(x \wedge y \in A\) and \(x \vee y \in B\). Given these preliminaries, the following lemma derives several useful properties of the optimization problem given in (2):

**Lemma 2.** Define \(C(\delta) := \{(p_2^s(\delta), \overline{v}^s(\delta)) \in \mathbb{R}^2; \ s.t. \ (p_1^s(\delta), p_2^s(\delta), \overline{v}^s(\delta)) \text{ is a solution to (2)}\}. Then,

(i) The set \(A := \{(p, \overline{v}) \in \mathbb{R}^2; \ p \in \arg \max_p (G(\overline{v}) - G(p)) p\}\) is a sublattice of \(\mathbb{R}^2\).

(ii) \(C(\delta)\) is non-decreasing in \(\delta\) respect to the strong set order. This implies that if the equilibrium is unique, \(\overline{v}^s(\delta)\) and \(p_2^s(\delta)\) are non-decreasing in \(\delta\).

(iii) The firm’s equilibrium profit is non-increasing in \(\delta\).

(iv) \(p_1^s(\delta) \geq p_2^s(\delta)\).

The lemma shows that as consumers value the future more and become more patient (i.e., as \(\delta\) increases), more consumers wait for the second period and the firm charges a higher second period price and earns lower profit. Furthermore, in equilibrium the firm skims the market, i.e., it begins with a high price and reduces the price in the second period. This leads us to the following result:

**Theorem 1.** Suppose the equilibrium prices to (2) are unique. Then, under any continuous and differentiable consumer valuation distribution:

(i) \(\overline{v}^s \geq p_1^m\) and \(p_2^s > p_2^m\).

(ii) A consumer with valuation \(v \in [p_2^m, p_2^s)\) does not obtain a unit under strategic behavior, but does obtain a unit under myopic behavior.

(iii) A consumer with valuation \(v \in [p_2^s, p_1^m)\) obtains a unit under both types of behavior, but pays a higher price under strategic behavior.
The theorem demonstrates that, for any continuous and differentiable valuation distribution, there always exists a nonempty set of consumers that are harmed by strategic behavior, i.e., they enjoy lower utility if consumers are strategic than they would if all consumers were myopic. There are two distinct mechanisms by which consumers can be harmed by strategic behavior. First, in case (ii), consumers with \( v \in [p^m_2, p^s_2] \) do not obtain a unit under strategic behavior. These consumers, who would have purchased (and obtained positive utility) under myopic behavior, are priced out of the market under strategic behavior. The reason for this is that strategic behavior results in higher valuation consumers purchasing in period 2 than under myopic behavior and this, in turn, leads the firm to raise the period 2 price to accommodate the higher valuations of period 2 customers. Hence, low valuation consumers are excluded from the market, specifically those with valuations between the myopic and the strategic period 2 prices. Second, in case (iii), consumers with \( v \in [p^s_2, p^m_1) \) always obtain a unit in period 2 under either type of behavior, but are forced to pay a higher price under strategic behavior due to the presence of higher valuation customers that caused the firm to raise the period 2 price. Taken in sum, cases (ii) and (iii) of the theorem provide our first results that indicate some consumers are actively harmed by strategic behavior. Bazhanov et al. (2015) find a similar result in a very different setting—consumers may be harmed by being more forward-looking, although in their model this is due to the destructive effects of competition between firms. The fact that consumers may be better off if they are myopic also echoes observations by Zhou et al. (2015) that in an oligopoly, firms may be better off if they are “non-strategic,” i.e., do not react to the actions of their competitors.

To facilitate our analysis and gain further insights, we assume throughout the remainder of the paper that consumer valuations are uniform on the interval (0, 1). It is straightforward to determine that with uniform valuations, there exists a unique SPNE under strategic behavior, and in this equilibrium \( \bar{v}^s = \frac{2-\delta}{27} \), \( p^s_1 = \frac{2-\delta}{6-4\delta} \), and \( p^s_2 = \frac{2-\delta}{6-4\delta} \). Comparing the resulting prices under each type of behavior, we note that \( p^m_2 < p^s_2 < p^s_1 < p^m_1 \), i.e., strategic behavior results in a lower period 1 price and a higher period 2 price than myopic behavior. The impact of strategic behavior on consumers in this case is illustrated graphically in Figure 1(a), which shows that consumers are, in fact, impacted by strategic behavior in five different ways.

Consumers with the lowest valuations—specifically, those with valuations in the bottom third of the distribution—never purchase a unit under either type of behavior; hence, these consumers always earn zero utility, and they effectively feel no impact of strategic behavior (segment N in the figure). On the other hand, consumers with moderate valuations—that is, those with valuations in the middle third of the distribution, segments H1 and H2 in the figure—are harmed by strategic behavior similarly to the results in Theorem 1. Consumers with \( v \in \left[ \frac{2}{3}, \frac{2-\delta}{6-4\delta} \right) \) do not obtain a unit under strategic behavior (segment H2) whereas consumers with \( v \in \left[ \frac{2-\delta}{6-4\delta}, \frac{2}{3} \right) \) always obtain a unit in period 2 under either type of behavior, but pay a higher price under strategic behavior (segment H1). Note that the set of consumers who pay a higher price
under strategic behavior includes some who, in equilibrium, strategically delay a purchase themselves, i.e.,
some consumers with valuations in the interval \([p_1^m, p_2^m]\). Despite the fact that these consumers engage in
strategic waiting, they would have been better off had all consumers been myopic; in that case, they still
would have purchased in period 2 (because the period 1 price would have been higher than their valuations)
but, due to the absence of even higher valuation period 2 customers strategically delaying from period 1, the
firm would set a lower period 2 price and increase the utility of these consumers. Lastly, consumers with
the highest valuations benefit from strategic behavior, again in two ways. Consumers with \(v \in \left[ \frac{2}{3}, \frac{2-\delta}{3-2\delta} \right] \)
purchase in period 1 under myopic behavior, but strategically delay and purchase in period 2 under strategic
behavior (and hence obtain the product at a lower price); this is segment B2 in the figure. Consumers with
\(v \in \left[ \frac{2-\delta}{3-2\delta}, 1 \right] \) purchase in period 1 under both types of behavior, but do so at a lower price under strategic
behavior (segment B1 in the figure). Hence, these consumers—who have the highest valuations of all—never
strategically wait themselves, but benefit from the strategic behavior of their fellow consumers.

In addition, observe that the overall sizes of the segments that are indifferent to, harmed by, and benefitted
by strategic behavior is insensitive to \(\delta\), the consumer discount factor. This occurs because these sets are
defined by the myopic prices, which are independent of \(\delta\); specifically, consumers with valuations less than \(p_2^m\)
are indifferent to strategic behavior (segment N), consumers with valuations between \(p_2^m\) and \(p_1^m\) are harmed
by strategic behavior (the union of segments H1 and H2), and consumers with valuations greater than \(p_1^m\)
benefit from strategic behavior (the union of segments B1 and B2). However, within each of these terciles,
the way in which consumers are harmed by or benefitted by strategic behavior shifts as \(\delta\) increases: for
instance, a fraction $\frac{\delta}{18-12\delta}$ of consumers are deprived of the item under strategic behavior, while a fraction $\frac{6-5\delta}{18-12\delta}$ are forced to pay a higher price under strategic behavior, hence as $\delta$ increases, a larger fraction of this set is harmed due to being priced entirely out of the market and a smaller fraction is harmed due to paying a higher price.

As part (b) of the figure shows, under a uniform valuation distribution, a majority of customers do not benefit from strategic behavior: for a third of the population (those with the lowest valuations) the value of strategic behavior is zero, while for another third of the population (those with moderate valuations) the value of strategic behavior is negative. Only consumers with valuations in the highest third of the distribution benefit from strategic behavior. Hence, strategic behavior is beneficial to a minority of the consumer population, and indeed those that benefit are precisely the consumers with the highest valuations. We note here that while the specific sizes of the segments that benefit from and are harmed by strategic behavior will, naturally, depend on the distribution of consumer valuations, it is true that under any continuously differentiable valuation distribution, a nonempty set of consumers is worse off under strategic behavior. Hence, the result that strategic behavior can be detrimental to some consumers is not sensitive to the choice of the consumer valuation distribution.\(^2\)

Having derived the impact of strategic behavior on individual consumers, we may now determine the impact on the entire consumer population, the firm, and society as a whole:

**Theorem 2.** When consumer valuations are uniform on $(0, 1)$,

(i) The value of strategic behavior to the entire consumer population is positive ($CV > 0$).

(ii) The value of strategic behavior to the firm is negative ($FV < 0$).

(iii) The value of strategic behavior to society is negative ($SV < 0$).

Part (i) of Theorem 2 shows that despite the fact that strategic behavior harms some consumers, total consumer surplus is higher when consumers are strategic. Thus, the gain in high valuation consumer surplus more than outweighs the loss in low and moderate valuation consumer surplus due to strategic behavior, which can be seen in Figure 1(b). The value of strategic behavior to the firm is, as expected, negative; interestingly, though, the value of strategic behavior to society as a whole is negative, meaning strategic behavior reduces social welfare. This shows that even though some consumers (specifically high valuation consumers) are better off under strategic behavior, this does not make up for the combined reduction in moderate valuation consumer surplus and firm profit. Figure 2 graphically illustrates these results. Observe that, in Figure 2(c), the gap between social welfare under myopic and strategic settings is increasing in $\delta$.

\(^2\)In contrast, this result is sensitive to the assumption that the firm correctly recognizes that its consumers are strategic and optimally accounts for their behavior by adjusting prices. If the firm does not do this, e.g., because it is unaware that consumers are strategic or incorrectly adjusts for strategic behavior (as laboratory experiments suggest may be plausible; see Kremer et al. 2015), consumers may benefit more from strategic behavior.
In other words, as strategic consumers become more patient, they harm social welfare more, compared to the myopic case. This is consistent with Figure 1(a), which showed that as $\delta$ increases, more consumers are harmed by being excluded from the market altogether (rather than simply paying a higher price) due to strategic behavior.

Taken as a whole, these results illustrate that strategic consumer behavior is neither beneficial to all consumers nor to society. This behavior does not represent consumers simply taking surplus from the firm in a zero-sum game: it reduces firm profit, causes some consumers to be excluded from the market or pay a higher price, and only benefits consumers with the highest valuations. As a result, social welfare is lower under strategic behavior than under myopic behavior. This fact motivates us to examine precisely how consumers may choose to be strategic, and what the firm can do to influence that choice, in the following section.

5 Endogenous Behavior: Choosing to be Strategic

In the literature on strategic consumer behavior and multiperiod pricing, an almost universal assumption is that consumer behavior is exogenous—that is, each individual consumer is assumed to follow either a myopic or strategic purchasing rule, but does not choose between these two types of purchasing rules. However, in practice, whether or not a consumer considers a strategic delay when making her initial purchasing decision is unlikely to be a completely exogenous trait; rather, it is plausible that rational consumers, aware of the costs and benefits of employing a strategic purchasing rule and subsequently executing the optimal purchasing strategy, decide which purchasing rule to adopt. In this section, we consider precisely this dynamic by endogenizing the consumer choice of purchasing rule.

Specifically, we consider a model in which all consumers are initially myopic—that is, they employ
a myopic purchasing rule by default—but they may choose to follow a strategic purchasing rule if they anticipate that this will increase their utility. Aside from any potential benefits (i.e., the ability to obtain the item at a lower price), adopting a strategic purchasing rule and implementing an optimal purchasing strategy also comes with a cost. For example, a customer that chooses to adopt a strategic purchasing rule will have to calculate her optimal purchase period (in our stylized model, period 1 or 2), which will require costly effort, and, if she further decides to strategically delay her purchase, she must actively monitor the firm to obtain the item as soon as a markdown occurs (the precise timing of which may be unpredictable) and make a return visit to the physical store or website, both of which incur some additional costs.\footnote{Recent empirical estimates by Moon et al. (2015) using data from an online retailer place the dollar value of similar “consumer monitoring costs” between $2 and $25 per visit to the store’s website; for a brick-and-mortar retailer, costs are likely to be even greater.} While, in reality, consumers may exert varying degrees of effort and, as a result, may end up possessing varying effort costs and degrees of strategic behavior, we abstract away from such details and assume that consumers either exert zero effort, meaning they remain “myopic,” or precisely enough effort to become fully “strategic.” In the latter case, the effort required to achieve this comes with a positive cost $k \geq 0$, which is the same for all consumers regardless of their valuation.

When choosing whether to adopt a strategic purchasing rule, each consumer has a belief $\hat{\eta}(v)$ about the incremental value they would obtain relative to the myopic purchasing rule, i.e., they believe that if they adopt a strategic purchasing rule, their surplus will increase by $\hat{\eta}(v)$. Following the rational expectations framework (Su & Zhang 2008; Cachon & Swinney 2009; Cachon & Feldman 2015b), we assume that these beliefs are correct in equilibrium. Consumers might develop these “rational expectations” of the value of strategic behavior from their past shopping experience with the firm or with other similar firms; based on this experience, each consumer knows how much her net utility changes if she adopts a strategic purchasing rule and she chooses to become strategic only if her net change is positive. Note $\hat{\eta}(v)$ may depend on the individual consumer’s valuation. We emphasize that while consumers have \textit{ex ante} rational expectations about the net value of adopting a strategic purchasing rule, actually implementing that rule requires exerting effort and incurring the effort cost $k$; hence, there is a distinction between knowing the potential value of strategic behavior and being able to realize that value by implementing the optimal purchasing strategy. Thus, in our model each individual consumer begins the game as myopic but \textit{rational}, and chooses to remain myopic or adopt a strategic purchasing rule to maximize her own utility. We say that a consumer who chooses to adopt a strategic purchasing rule chooses to “become strategic,” i.e., forward-looking in the sense of the previous literature on inter-temporal consumer purchasing behavior (Su & Zhang 2008; Aviv & Pazgal 2008). After this decision, consumers who choose to become strategic exert effort to find and implement the
optimal purchasing strategy.\(^4\)

The utility earned by a myopic consumer is \(u_1(v)\) if she purchases in period 1 (i.e., if \(u_1(v) \geq 0\)), \(u_2(v)\) if she purchases in period 2 (i.e., if \(u_1(v) < 0\) and \(u_2(v) \geq 0\)), and zero otherwise; the utility earned by a strategic consumer is \(\max(u_1(v), u_2(v), 0) - k\). The rational expectations assumption implies that a consumer chooses to be strategic if her utility from behaving in this manner is greater than her utility from remaining myopic, i.e., if \(\hat{\eta}(v) > 0\), where \(\hat{\eta}(v)\) is the equilibrium incremental value of a strategic purchasing rule. The rational expectations assumption also implies that, in deciding between a myopic and a strategic purchasing rule, a consumer is only required to have correct expectations about \(\hat{\eta}(v)\) given the first period price, i.e., she does not need to perfectly anticipate every parameter that enters her utility from a strategic purchasing rule separately (such as the second period price or the cost of being strategic) nor is she required to be able to calculate the utility \(\max(u_1(v), u_2(v), 0) - k\) precisely and find the optimal purchasing period. Only a consumer who decides to follow a strategic purchasing rule pays the cost \(k\) and determines \(u_2(v)\). The cost of being strategic, \(k\), is assumed to be sunk once paid, and thus after choosing to be strategic, consumers ignore this cost when optimally timing their purchases. Figure 3 depicts the consumer decision process in the first period.

We denote the endogenous behavior model by a superscript \(k\). Note that this is indexed by the cost of becoming strategic; in the special case where \(k = 0\), it is trivially true the model reduces to the exogenous behavior model with strategic consumers. Conversely, if \(k\) is sufficiently large (under uniform \((0, 1)\) valuations, greater than 1) then no consumer will ever choose to be strategic, and the model reduces to the exogenous behavior model with myopic consumers. Thus, the endogenous behavior model can be thought of as a generalization of both exogenous behavior models.

Our first result with this model provides the equilibrium prices and consumer actions when consumers

\(^4\)This model of “endogenous strategic behavior” is also related to broader theories of bounded rationality (Simon 1978) and, in particular, satisficing (Tyson 2008). A consumer in our model can be thought of as engaging in something analogous to satisficing behavior because she remains myopic (and does not strategically wait) if her gain from becoming strategic is less than \(k\), i.e., if being myopic leads to a payoff within \(k\) of her optimal payoff. The key difference is that in our model consumers actually pay the cost \(k\) if they become strategic, while under satisficing \(k\) is not a real cost; this feature impacts the equilibrium total consumer surplus and social welfare calculations but not the equilibrium consumer decisions, leading to similar insights. Also related is the concept of “rational ignorance,” in which consumers may rationally choose to obtain less than perfect information if the cost of obtaining information is non-zero (Downs 1957; Martinelli 2006; Hu et al. 2015); our model may be thought of as “rational myopia” in a similar spirit to this line of work.
may individually choose whether to adopt a strategic purchasing rule:

**Lemma 3.** With endogenous behavior and uniform valuations on \((0,1)\), there exists a unique SPNE in which all consumers with valuations greater than \(\bar{v}^k\) purchase in period 1 and all consumers with valuations less than \(\bar{v}^k\) wait until period 2. Furthermore:

(i) If \(k \geq \frac{\delta}{3}\), all consumers choose to be myopic, and \(p_1^k = \frac{2}{3}\), \(p_2^k = \frac{1}{3}\), and \(\bar{v}^k = \frac{2}{3}\).

(ii) If \(\frac{24-\delta^2}{6-2\delta} \leq k < \frac{\delta}{3}\), all consumers choose to be myopic, and \(p_1^k = \frac{2k}{\delta}\), \(p_2^k = \frac{k}{\delta}\), and \(\bar{v}^k = \frac{2k}{\delta}\).

(iii) If \(0 \leq k < \frac{24-\delta^2}{6-2\delta}\), consumers with \(v \in [p_1^k, \bar{v}^k)\) choose to be strategic, and \(p_1^k = \frac{(2-\delta)^2+2(1-\delta)k}{6-4\delta}\), \(p_2^k = \frac{2-\delta-2k}{6-4\delta}\), and \(\bar{v}^k = \frac{2-\delta-2k}{3-2\delta}\).

In part (i), the cost of executing a strategic purchasing rule is sufficiently high that no consumer would ever choose strategic behavior regardless of the prices set by the firm; hence, the myopic outcome is replicated. In part (ii), it is also true that no consumer chooses to be strategic in equilibrium; however, this outcome is achieved because the firm’s prices have induced such behavior. In particular, as \(k\) decreases from \(\delta/3\), the firm sets a lower period 1 price to induce consumers to be myopic. In part (iii), the cost of executing a strategic purchasing rule is sufficiently low that the firm cannot profitably “price out” strategic behavior, as doing so would require a significant price reduction in period 1; hence, in equilibrium, the firm prices higher than the level that eliminates strategic behavior, and some consumers choose to be strategic (and, in addition, strategically wait for period 2). Specifically, these are consumers with valuations in the interval \([p_1^k, \bar{v}^k)\). Interestingly, while many theoretical models that incorporate both myopic and strategic consumers assume that consumer behavior is independent of consumer valuations, part (iii) of the lemma suggests that only moderate valuation consumers will choose to become strategic, calling into question this common assumption from the literature.

Note that the firm’s equilibrium prices and the threshold consumer valuation are not necessarily monotonic in \(k\). Specifically, \(p_1^k\) is always (weakly) increasing in \(k\), but the other two equilibrium quantities (\(p_2^k\) and \(\bar{v}^k\)) are non-monotonic: in case (i) these values are independent of \(k\), in case (ii) they are increasing in \(k\), and in case (iii) they are decreasing in \(k\). These patterns are depicted graphically in Figure 4. The reason for this non-monotonicity is the aforementioned way in which the firm uses the period 1 price to eliminate strategic behavior: initially as \(k\) decreases from \(\delta/3\), the firm reduces the period 1 price rapidly to induce consumers to be myopic, which means that \(\bar{v}^k\) initially decreases as \(k\) decreases. However, as \(k\) continues to fall, this becomes too expensive for the firm and as a result the firm “gives up” on eliminating strategic behavior. After this point, \(\bar{v}^k\) grows as \(k\) decreases, i.e., as being strategic becomes less costly, more consumers choose to be strategic. Because the period 2 price is simply \(\bar{v}^k/2\) under uniform valuations, this value exhibits the same behavior as \(\bar{v}^k\), leading to a non-monotonic period 2 price.
Comparing the equilibrium derived in the lemma to the equilibrium under exogenous behavior, observe that under endogenous behavior, the firm should set a first period price between the two extreme cases (i.e., between the myopic and strategic optimal prices, found at $k = 0$ and $k \geq \frac{\delta}{3}$, respectively), but the optimal second period price may actually be lower than under either of the exogenous behavior models. The reason for this is that under endogenous behavior, the firm may (at intermediate $k$) intentionally set a very low period 1 price to eliminate strategic behavior; in turn, this implies very low valuations of period 2 customers, and hence a low optimal period 2 price. As a result, both the period 1 and period 2 prices under endogenous behavior may be lower than the prices under purely myopic behavior; this is in contrast to the exogenous strategic behavior model, which recommends firms lower the period 1 price but raise the period 2 price compared to the myopic optimal levels. This shows that the firm’s optimal dynamic pricing policy is qualitatively different when strategic behavior is endogenously determined than when it is exogenous, and setting a strictly lower price path may be an optimal response to endogenous strategic behavior. In other words, it is possible that one of the most basic managerial insights about the optimal response to strategic behavior—that firms should raise the final period price in response to strategic consumers—may no longer be true when consumers can endogenously choose to be strategic, and in fact a very low period 2 price may be optimal.

Also note that under a uniform valuation distribution, a minority of the consumer population will choose to be strategic. Specifically, the maximum proportion of consumers who choose to be strategic is 50%; the
maximum occurs when $k \to 0$ and $\delta \to 1$. These proportions are quite sensitive to $\delta$, and as $\delta$ decreases they fall rapidly; for instance, when $\delta = 0.8$, 34% of consumers choose to be strategic; this is remarkably close to estimates of the prevalence of strategic behavior found in the empirical literature (e.g., Li et al. 2014).

In addition, despite the fact that consumers may voluntarily choose whether to be strategic, it remains true that not all consumers benefit from strategic behavior, as the following theorem shows:

**Theorem 3.** Let $\bar{k} = \frac{2\delta - \delta^2}{6 - 2\delta}$. Then, under endogenous behavior and uniform valuations on $(0, 1)$,

(i) If $0 \leq k \leq \frac{\delta}{6}$, all consumers with $v \in \left(\frac{1}{3}, \frac{2}{3}\right)$ are strictly worse-off under strategic behavior than if all consumers were myopic. Furthermore, in this set, consumers with $v \in \left[\frac{(2-\delta)^2 + 2(1-\delta)k}{6 - 4\delta}, \frac{2}{3}\right)$ choose to become strategic.

(ii) If $\frac{\delta}{6} < k \leq \bar{k}$, all consumers with $v \in \left[\frac{(2-\delta)^2 + 2(1-\delta)k}{6 - 4\delta}, \frac{2}{3}\right)$ are strictly worse-off under strategic behavior than if all consumers were myopic. Furthermore, in this set, consumers with $v \in \left[\frac{(2-\delta)^2 + 2(1-\delta)k}{6 - 4\delta}, \frac{2-\delta-2k}{3-2\delta}\right)$ choose to become strategic.

(iii) If $\bar{k} < k < \frac{\delta}{3}$, all consumers with $v \in \left[\frac{2k}{3}, \frac{2}{3}\right)$ are strictly worse-off under strategic behavior than if all consumers were myopic. Furthermore, no consumer chooses to become strategic.

Interestingly, even when consumers may freely choose to become strategic or remain myopic, there is always a nonempty set of consumers who are worse off than if the entire population were forced to be myopic. This will clearly be true for those consumers who are priced out of the market due to strategic behavior and those consumers who always buy in period 2 due to a period 1 price higher than their valuations. However, in cases (i) and (ii) of the theorem, some consumers that are harmed by strategic behavior choose, themselves, to adopt a strategic purchasing rule, yet are worse off than if they had not had the option of becoming strategic. In case (iii), no consumer chooses to be strategic, but the threat of strategic behavior causes the firm to react by changing its prices in such a way that some consumers are worse off (in particular, those who would buy in period 2, and obtain a large surplus, under myopic behavior, but end up purchasing in period 1, at a smaller surplus, under endogenous behavior).

Comparing the segment sizes under the endogenous case to those under the exogenous behavior case with uniform valuations (discussed in §4), it is clear that in case (i) of the theorem, the same consumers are harmed by strategic behavior as in the exogenous model, while in cases (ii) and (iii), fewer consumers are harmed by strategic behavior in the endogenous behavior case than in the exogenous behavior case; this is due to the fact that endogenous behavior reduces the number of consumer who are strategic in equilibrium, thereby reducing, but never eliminating (unless $k > \delta/3$), the negative impact on some individual consumers compared to an exogenous model in which all consumers are strategic.
6 Implications

Having derived the equilibrium prices and consumer actions under endogenous behavior in the previous section, we now discuss two important implications of these results: first, the impact of increasing the cost of strategic behavior on the firm, consumers, and society, and second, the impact of endogenous behavior on how the firm values commitment strategies designed to mitigate strategic waiting.

6.1 Increasing the Cost of Strategic Behavior

Lemma 3 illustrates that in order to reduce strategic behavior amongst its customers, the firm could make being strategic more “costly” for them, i.e., it could attempt to increase $k$. How might firms go about increasing the cost of strategic behavior? One way to accomplish this might be through offering equivalent but more complicated pricing schemes to consumers that require more effort to calculate and thus to compare the value of purchasing in different periods. For example, the firm can offer stacking discount schemes (e.g., 40% + an additional 10% discount) instead of single price discounts. Another way to increase the cost of executing a strategic purchasing rule is to make markdowns less frequent and more random in nature (Moon et al. 2015), necessitating consumers monitor the store more frequently or otherwise exert more effort to learn about pricing patterns and identify precisely when a price reductions occurs.

In fact, several of the most successful apparel retailers in the world, like Zara and H&M, have built their business strategy around precisely this approach, “training” their customers to be myopic by, among other strategies, infrequent and unpredictable price reductions (Ghemawat et al. 2003; Cachon & Swinney 2011). While mitigating strategic behavior with a captive customer base seems beneficial, in reality, customers have outside options, such as purchasing from competitors or reducing or forgoing consumption, and faced with a decrease in their own utility due to firm efforts to minimize strategic behavior, in practice consumers may choose to abandon the firm. This presents the following riddle: if strategic behavior is good for consumers, why do so many consumers shop at companies that make it difficult to be strategic? How can these companies be so successful in the marketplace? On one hand, it is possible that companies such as Zara and H&M succeed in spite of the fact that they make strategic behavior difficult for consumers, e.g., because they offer other benefits to consumers like better design, or because the benefits of mitigating strategic behavior for consumers who continue to shop at the firm outweigh any demand loss that results from reducing consumer utility. On the other hand, our model indicates that a different explanation may be possible as well, which the following theorem illustrates:

**Theorem 4.** Let $\bar{k} = \frac{2\delta - \delta^2}{\delta - 2\delta}$. Under endogenous behavior and uniform valuations on $(0, 1)$:

(i) Firm profit is increasing in $k$. 

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(ii) Total consumer surplus achieves its maximum at either \( k = 0 \) or \( k = \bar{k} \). Specifically, let \( x^* \) be the first root of \( x^3 - 12x^2 + 24x - 12 = 0 \). Then, \( x^* \approx 0.8 \), and if \( \delta > x^* \), consumer surplus is maximized at \( k = \bar{k} \). Otherwise, consumer surplus is maximized at \( k = 0 \).

(iii) Social welfare is quasi-concave in \( k \) and maximized at \( k = \bar{k} \).

Part (i) of the theorem confirms our intuition that the firm benefits from a higher cost of strategic behavior. Interestingly, part (ii) of the theorem shows that consumers may also benefit from higher \( k \): when consumers are relatively patient (\( \delta \geq 0.8 \)), total consumer surplus is maximized at \( k = \bar{k} \). This is due to the fact that when consumers are patient and \( k \) is small, “too many” consumers will adopt a strategic purchasing rule, which causes the firm to respond by adjusting its prices in a way that is detrimental to total consumer welfare. In this case, the consumer population would be better off with a larger \( k \), in which fewer consumers will choose to be strategic but the firm’s prices are more attractive. Note that \( \bar{k} \) is exactly the minimum \( k \) at which no consumers, in equilibrium, choose to be strategic. Figure 5(a) illustrates this case. Part (iii) shows that social welfare is maximized at an intermediate \( k \); this is the same point that maximizes consumer welfare. Thus, not only are consumers potentially better off with a higher cost of strategic behavior, but the firm and society are as well. These effects are depicted in Figure 5(b). The reason for this is that, when the cost of being strategic is low, strategic behavior has the flavor of a Prisoner’s Dilemma: many consumers, individually, want to be strategic, but the result of these individual decisions is that consumers reduce social welfare and, as we saw in the exogenous behavior model, the individual utility of moderate valuation consumers. Hence, consumers “over-strategize” when the cost of engaging in this behavior is low, to the detriment of the firm and society as a whole. This illustrates that an opportunity exists for a Pareto-improving outcome in which the firm makes it more difficult for consumers to be strategic, and both consumers and the firm benefit as a result.

These results suggest that successful apparel companies such as Zara and H&M may not succeed in spite of the fact that they make it hard for consumers to be strategic; rather, they may succeed precisely because of this fact. Theorem 4 shows that if consumers are sufficiently patient, making strategic behavior more difficult—to the point that all consumers, in equilibrium, choose to be myopic—increases not only the firm’s profit, but also consumer and social welfare. In other words, these firms make consumers act myopically, and consumers and the firm are both better off because of it. While we do not explicitly model competition or long term industry dynamics, we posit that this, in turn, may attract more demand over time and cause these firms to grow their customer base, leading to the observed phenomenon that a number of the most successful apparel retailers also do the most to minimize strategic behavior.
Making it costlier to be strategic is not the only approach a firm could take to mitigate strategic consumer behavior. Indeed, previous work on strategic consumer behavior has identified several methods that a firm can employ to reduce strategic waiting and increase profits. Perhaps the most important and well-studied such strategy is price commitment, where the firm pre-announces and commits to a series of prices at the beginning of the selling season rather than setting them dynamically (Aviv & Pazgal 2008; Elmaghraby et al. 2008; Su & Zhang 2008; Elmaghraby et al. 2009; Mersereau & Zhang 2012). Although previous studies consider different settings and assumptions, such as the number of price changes or the consumer valuation distribution, they all find that committing to prices can reduce the negative impact of strategic waiting to the firm by credibly raising the price in later periods, giving forward-looking consumers less incentive to strategically delay a purchase.\footnote{An exception is Cachon & Swinney (2009), who find dynamic pricing can perform better than price commitment; however, in their model this result is driven by the ability of dynamic pricing to react to fluctuations in uncertain demand, a feature not present in our model of deterministic demand.} Price commitment, rather than increasing the cost of strategic behavior (as discussed in the preceding section), works by reducing the “value” of a strategic purchasing delay. However, while price commitment has demonstrated benefits when consumer behavior is exogenously specified, its effects on the endogenous behavior model have not been considered; hence, in this section we analyze the performance of price commitment under endogenous behavior.\footnote{Similar to price commitment, inventory commitment allows the firm to commit to a pre-specified amount of inventory in future periods. This strategy can generate value by creating availability risk which encourages consumers to purchase earlier (Su 2007; Liu & van Ryzin 2008; Zhang & Cooper 2008; Levin et al. 2010). In our model, because demand is deterministic, price and inventory commitment are in fact equivalent. Thus, in what follows, although we state our results in terms of price commitment, all results also apply to inventory commitment.} We use the superscript $c$ to refer to price commitment with endogenous behavior.

6.2 Price Commitment and Endogenous Behavior

Figure 5. Consumer and social welfare under endogenous behavior for $\delta = 0.9$. 

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<tr>
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<th>Consumer Surplus</th>
<th>Social Welfare</th>
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<tr>
<td>1</td>
<td>0.10</td>
<td>0.05</td>
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<tr>
<td>2</td>
<td>0.11</td>
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(a) Consumer Surplus  
(b) Social Welfare
To begin our analysis, Lemma 4 replicates the result of Lemma 3 under a price commitment strategy:

**Lemma 4.** With price commitment, endogenous behavior, and uniform valuations on \((0, 1)\), there exists a unique SPNE in which all consumers with valuations greater than \(\bar{v}^c\) purchase in period 1 and all consumers with valuations less than \(\bar{v}^c\) wait until period 2. Furthermore:

(i) If \(k \geq \frac{\delta}{3}\), all consumers choose to be myopic, and \(p_1^c = \frac{2}{3}\), \(p_2^c = \frac{1}{3}\), and \(\bar{v}^c = \frac{2}{3}\).

(ii) If \(\frac{\delta - \delta^2}{3 - \delta} \leq k < \frac{\delta}{3}\), all consumers choose to be myopic, and \(p_1^c = \frac{\delta + k}{2\delta}\), \(p_2^c = \frac{\delta - k}{2\delta}\), and \(\bar{v}^c = \frac{\delta + k}{2\delta}\).

(iii) If \(0 \leq k < \frac{\delta - \delta^2}{3 - \delta}\), consumers with \(v \in [p_1^c, \bar{v}^c]\) choose to be strategic, and \(p_1^c = \frac{2 + k}{3 + k}\), \(p_2^c = \frac{\delta - k}{3 + k}\), and \(\bar{v}^c = \frac{2 - \delta^2 - \delta - 2k}{3 - 3\delta - 2k}\).

In many ways, the equilibrium under price commitment is similar to the equilibrium under dynamic pricing: in the first two cases, no consumer chooses to be strategic, while in the last case consumers with valuations slightly higher than the first period price choose to be strategic in equilibrium. However, observe that equilibrium prices are always monotonic (and increasing) in \(k\) under price commitment; because of this, the prices with endogenous behavior lie between the equilibrium prices under the two exogenous behavior models (i.e., corresponding to \(k = 0\) for the exogenous strategic model and \(k = 1\) for the exogenous myopic model). Importantly, it is easy to see that fewer consumers choose to adopt a strategic purchasing rule under price commitment than under dynamic pricing for any fixed \(k\). Therefore, keeping the cost of being strategic, \(k\), equal, the firm benefits from price commitment as it reduces consumer incentives to be strategic.

However, this argument ignores a critical detail: the cost of being strategic, \(k\), likely depends on the pricing strategy that the firm chooses. In particular, it is reasonable that the cost of being strategic is lower under price commitment than under dynamic pricing: by credibly announcing a second period price at the start of the selling season, price commitment makes it relatively easy for consumers to be strategic, as they no longer need to compute an expected second period price. This presents an interesting tension: on one hand, keeping the cost \(k\) equal, price commitment is beneficial as it mitigates consumer incentives to be strategic (consistent with previous works such as Aviv & Pazgal 2008). On the other hand, adopting a pricing strategy that makes it “easier” to be strategic may lower \(k\) and encourage more consumers to adopt a strategic purchasing rule. Given these opposite forces, it is not immediately clear which pricing strategy is most valuable to the firm. The following theorem formalizes this argument:

**Theorem 5.** Let \(k_c\) and \(k_d\) be the costs of strategic behavior under price commitment and dynamic pricing, respectively. Then, under endogenous behavior and uniform valuations on \((0, 1)\):

(i) If \(k_c = k_d\), firm profit is weakly greater under price commitment than under dynamic pricing. Furthermore, both pricing mechanisms yield the same profit if and only if \(k_c \geq \frac{\delta}{3}\) and \(k_d \geq \frac{\delta}{3}\).

(ii) For every discount factor \(\delta\) and every \(k_c < \frac{\delta}{3}\), there exists a unique threshold \(\tilde{k}_d(k_c, \delta) \in (k_c, \frac{\delta}{3})\), such that
dynamic pricing results in strictly greater firm profit than price commitment if and only if $k_d > \bar{k}_d(k_c, \delta)$.

The theorem shows that while price commitment dominates dynamic pricing when the costs of strategic behavior are equal (part (i)), dynamic pricing dominates if the costs of strategic behavior are sufficiently different (part (ii)). Figure 6 illustrates this tension by plotting the firm’s optimal pricing strategy as a function of $k_c$ and $k_d$; previous research, with exogenously specified strategic behavior, essentially focuses solely on the origin of the graph ($k_c = k_d = 0$). As the figure shows, for most of the parameter space, dynamic pricing is weakly optimal. Indeed, it is reasonable that the cost of strategic behavior is negligible with price commitment (i.e., $k_c \to 0$). In that case, dynamic pricing is optimal even for a small non-zero cost to strategic behavior ($k_d \geq 0.04$ when $\delta = 0.9$, for example). Thus, in contrast to numerous earlier works that demonstrate the (often significant) value of price commitment under exogenous strategic behavior, under endogenous behavior, price commitment can actually reduce firm profit if it results in a reduction of the cost of being strategic for consumers. This finding may provide a solution to a common puzzle found in the pricing literature: if price commitment is so effective at mitigating strategic waiting, why do most firms seem to use dynamic pricing instead? Our model suggests that one possible answer to this question is that price commitment is less effective at mitigating strategic behavior than previously believed because it makes it easier (and less costly) for consumers to be strategic. Combined with the benefits of dynamic pricing to match supply with stochastic demand, this fact may mean that, in practice, firms find little value in committing to future prices. Indeed, perhaps the most notorious practitioner of price commitment in practice, Filene’s Basement department store—famous for automatically marking down inventory by set percentages at regular intervals—experienced poor performance throughout the early 2000s and closed all stores in 2011; the firm eventually re-opened as an exclusively online retailer in 2015, no longer employing automatic markdowns (Radsken 2015).

Figure 6. Firm preference between dynamic pricing and price commitment as a function of the cost of strategic behavior ($k_d$, vertical axis, and $k_c$, horizontal axis).
More broadly, this discussion illustrates that it is important to consider how an alternative selling strategy designed to mitigate strategic waiting impacts consumer incentives to adopt a strategic purchasing rule in the first place. Some mitigation strategies, such as price commitment, seem likely to reduce the cost of strategic behavior; others, such as limiting inventory displays to obscure availability information (Yin et al. 2009) or rotating product assortment more frequently (Bernstein & Martínez-de Albéniz 2014) may increase the cost of strategic behavior, giving these strategies additional value beyond that which has been previously understood.

7 Conclusion

While strategic consumer behavior has received significant research and practical attention in recent years, a key question has, until now, gone unanswered: should consumers be strategic? In this paper, we have shown that the answer to this question is not as straightforward as it might seem. Although, in the absence of any costs, a strategic purchasing rule is clearly optimal for each individual consumer, in equilibrium many consumers (and society) are worse off than they would have been had all consumers followed a myopic purchasing rule. Motivated by this finding, we have investigated a model of endogenous consumer behavior in which individual consumers must choose whether to exert costly effort to adopt a strategic purchasing rule, with the goal of understanding how this choice impacts firm decisions and equilibrium consumer behavior.

Our analysis has several important implications. First, we have shown that when consumer behavior is endogenous, in contrast to the case when consumer behavior is exogenously specified, consumer (and social) welfare may be maximized when the cost of strategic behavior is strictly positive: if the cost is too low, too many consumers choose to be strategic, leading to a smaller market and higher prices. This suggests that firms may not only benefit themselves by increasing the cost of strategic behavior (e.g., by offering complicated sales schemes or making markdowns less predictable); they may also benefit consumers and society as a whole, highlighting why making it harder for consumers to be strategic may actually attract more consumers. Further research into this issue might study specific strategies to increase the cost of strategic behavior in greater detail. For instance, although we have abstracted away from the details of dynamic consumer learning to isolate our main research question, future work may attempt to investigate more detailed models of information gathering by consumers to explore precisely how firms can make learning more difficult and, as a result, strategic behavior more costly to execute.

Second, our results show that strategies to mitigate strategic behavior that are believed to perform well may in fact decrease profit if they impact the cost of being strategic. Using this logic, we have shown that committing to a pre-specified price path, long believed to be more effective than dynamic pricing at
mitigating strategic behavior, can in fact backfire and reduce firm profit if it also reduces the cost of strategic behavior for consumers. This may help to explain why dynamic pricing is far more prevalent in practice than commitment; in addition to the inherent ability of dynamic pricing to react to stochastic demand, in practice it may be the case that price commitment reduces the cost of strategic behavior enough that there is little or no behavioral benefit from this strategy.

Third, we have developed a novel model of endogenous strategic consumer behavior, and shown that considering the consumer choice to be strategic can significantly impact both firm and consumer optimal decisions. For the firm, this impact extends to both tactical decisions (i.e., the firm’s optimal dynamic pricing policy is non-monotonic in the cost of strategic behavior and may consist of lower prices in both periods than the myopic optimal prices) and strategic decisions (i.e., the firm may find value in raising the cost of strategic behavior and in pricing dynamically instead of committing to a price path). Indeed, our model makes empirically testable predictions about these decisions that run counter to previous theoretical research that assumes exogenous behavior that may be interesting avenues to explore in future research. In addition, future theoretical work may employ our endogenous behavior model to investigate the impact of the consumer choice to be strategic on other firm actions, such as product assortment or supply chain design.

Lastly, while we have focused on a particular type of strategic behavior, i.e., inter-temporal purchase timing, many other types of more broadly defined “strategic” consumer actions have been identified in the literature (e.g., choosing when to arrive to a service system, Lariviere & Van Mieghem 2004, or choosing whether to shop given limited inventory availability or price information, Dana & Petruzzi 2001; Cachon & Feldman 2015b). An intriguing issue is whether strategic behavior in other contexts can be detrimental to consumers in the same way that strategic behavior in our model is, which could have serious consequences for the way the firm manages its marketing efforts and operations, and the way consumers are advised to behave.

References


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### A Proofs

**Proof of Lemma 1.** For any pair of prices $\hat{p}_1$ and $\hat{p}_2$, a consumer would purchase in the first period if and only if $v - \hat{p}_1 \geq \max(\delta(v - \hat{p}_2), 0)$. The result follows from noting that $v - \hat{p}_1 - \max(\delta(v - \hat{p}_2), 0)$, is an increasing function of $v$.

**Proof of Lemma 2.** (i) One can see that $g(\hat{v}) = \max_p(G(\hat{v}) - G[p])p \geq 0$ and since $\hat{R}$ is a lattice, then from Corollary 2 of Milgrom & Shannon (1994), $\max_p(G(\hat{v}) - G[p])p$ is a sublattice of $\hat{R}$. However, we need to prove that $A$ is also a sublattice of $\hat{R}^2$. Let $v_2 \geq v_1$; if $(v_1, p_1) \in A$ and $(v_2, p_2) \in A$, then $(v_1, p_1) \land (v_2, p_2) = (v_1, \min(p_1, p_2))$ and $(v_1, p_1) \lor (v_2, p_2) = (v_2, \max(p_1, p_2))$. From Theorem 4 of Milgrom & Shannon (1994) $\max_p(G[v_2] - G[p])p \geq \max_p(G[v_1] - G[p])p$ in the strong set order. Hence, if $p_1 \in \arg \max_p(G[v_1] - G[p])p$ and $p_2 \in \arg \max_p(G[v_2] - G[p])p$, then $\min(p_1, p_2) \in \arg \max_p(G[v_1] - G[p])$, hence $(v_1, \min(p_1, p_2)) \in A$. Similarly one can see that $(v_2, \max(p_1, p_2)) \in A$. As such $A$ is a lattice.

(ii) First of all note that since $\lim_{p \to +\infty}(G[\hat{v}] - G[p])p \leq 0$ and $\lim_{p \to 0}(G[\hat{v}] - G[p])p = 0$, then if $G[\hat{v}] > 0$ the maximum of $(G[\hat{v}] - G[p])p$ would be an interior solution. Therefore, $\arg \max_p(G[\hat{v}] - G[p])p \subseteq \{p : \hat{p}_G[p] = G[\hat{v}]\}$. Thus, in equilibrium, $G[\hat{v}] = G[\hat{p}_2] + p_2 \hat{p}_2 \Rightarrow G[\hat{v}] \geq G[\hat{p}_2]$. We claim that in equilibrium $\hat{v} \geq p_2$. If $G[\hat{v}] > G[\hat{p}_2]$, then there is nothing to prove. Also in equilibrium, if $G[\hat{v}] = G[\hat{p}_2] \neq 0$, the firm receives 0 in the second period. However, there exists some $p > 0$, such that $G[\hat{v}] > G[p]$ and yields a positive revenue, which is a contradiction with optimality of $p_2$ for the second period. If $G[\hat{v}] = G[\hat{p}_2] = 0$, then the firm receives revenue $p_1$. In this case, $\hat{v}$ should be such that $\hat{v} = \sup \{v : G(v) = 0\}$, because otherwise one can increase $p_1$ and since $v \geq p_1$, find a higher $\hat{v}$ and a higher revenue; therefore, $\hat{v} \geq p_2$. Consequently, one can replace constraint $\hat{v} = \{\min \hat{v}, \text{s.t. } \hat{v} - p_1 \geq \delta(\hat{v} - p_2)^+\}$ by $\hat{v} - p_1 = \delta(\hat{v} - p_2)$. From this constraint, one can replace $p_1$ to obtain the following equivalent optimization problem:

$$\max_{p_2, \hat{v}} \pi(\hat{v}, p_2, \delta) = (1 - G[\hat{v}])((1 - \delta)\hat{v} + \delta p_2) + (G[\hat{v}] - G[p_2])p_2$$

s.t. $p_2 \in \arg \max_p(G[\hat{v}] - G[p])p$
For simplicity of notation we use \( v \) instead of \( \bar{v} \) and \( p \) instead of \( p_2 \) in what follows. From Lemma 2, the feasible set is a sublattice of \( \mathbb{R}^2 \). Also one can see that \( \frac{\partial \pi(v,p,\delta)}{\partial p_1} = (1 - \delta)q[v] \geq 0 \). In addition, if \((\bar{v}, \bar{p})\) and \((\bar{v}, \hat{p})\), be two elements of the feasible set such that \( \bar{v} \geq \hat{v} \), then from Lemma 2, \((\bar{v}, \bar{p}) \lor (\bar{v}, \hat{p}) = (\hat{v}, \bar{p})\). Hence, \( \pi(v, p, \delta) \) is supermodular in \( (v, p) \) and consequently is a quasiquasimodular function.

To be able to use Theorem 4 of Milgrom & Shannon (1994), one should prove that \( \pi_1(v, p, \delta) \) has the single crossing property in \((v, p, \delta)\). Note that a frequently used sufficient condition for this to hold is having the increasing difference property. However, this sufficient condition does not hold here. Therefore, we apply the definition directly. A function \( f : X \times T \to \mathbb{R} \), is said to have single crossing property in \((x, t)\), if the following two conditions hold when \( x' > x'' \) and \( t > t'' \):

1) \( f(x', t'') \geq f(x'', t') \Rightarrow f(x', t') \geq f(x'', t'') \),
2) \( f(x', t'') > f(x'', t') \Rightarrow f(x', t') > f(x'', t''). \)

To check this let \( p' \geq p'' \), \( v' \geq v'' \), and \( \delta' \geq \delta'' \). To check the first condition assume that

\[
(1 - G[v'])((1 - \delta'')v' + \delta''p') + (G[v'] - G[p'])p' \\
\geq (1 - G[v''])((1 - \delta'')v'' + \delta''p'') + (G[v''] - G[p''])p''
\]

Then we have

\[
\delta''((p' - v')(1 - G[v']) - (p'' - v'')(1 - G[v''])) + v'(1 - G[v']) - v''(1 - G[v'']) \\
+ (G[v'] - G[p'])p' - (G[v''] - G[p''])p'' \geq 0
\]

Note that only first part of this equation depends on \( \delta'' \). Therefore, if \((p' - v')(1 - G[v']) - (p'' - v'')(1 - G[v'']) \geq 0\), then replacing \( \delta'' \) by \( \delta' \), the equation remains positive. Hence, we only need to prove for the case where \((p' - v')(1 - G[v']) - (p'' - v'')(1 - G[v'']) < 0\). Then the left side of inequality attains its minimum value when \( \delta' = 1 \) and it is sufficient to show that for \( \delta' = 1 \), the left side of the inequality remains nonnegative. Replacing \( \delta'' = 1 \), one has,

\[
1 \times \left((p' - v')(1 - G[v']) - (p'' - v'')(1 - G[v''])\right) + v'(1 - G[v']) \\
- v''(1 - G[v'']) + (G[v'] - G[p'])p' - (G[v''] - G[p''])p'' = \\
p'(1 - G[p']) - p''(1 - G[p''])
\]

To show that this is positive it is enough to show that \( p(1 - G[p]) \) is increasing in \( p \). Consequently, it is enough to argue that \((pG[p])' \leq 1 \). However, note that as argued the solution to \( \max_p(G[v] - G[p]) \) is an interior solution and satisfies \((pG[p])' = G[v] \leq 1 \), which is what we wanted. To see the second condition of single crossing property, note that now if \((p' - v')(1 - G[v']) - (p'' - v'')(1 - G[v'']) > 0\), there is nothing to prove. For \((p' - v')(1 - G[v']) - (p'' - v'')(1 - G[v'']) < 0\), then the left side of the inequality is strictly decreasing in \( \delta \) and for \( \delta = 1 \) is non-negative. But notice that \( \delta \) is strictly less than 1, hence, the left side would be strictly positive.

One can also simply replace \( \geq \) with \( > \), to see the second condition of single crossing property. Hence, since the feasible set is lattice, the objective function is quasiquasimodular and has the single crossing property one can use Theorem 4 of Milgrom & Shannon (1994) to see the result.

(iii) As argued, in the previous part, \( \bar{v} \geq p_2 \). Now if we differentiate from the objective function respect to \( \delta \) one sees that \( \frac{\partial \pi(v,p,\delta)}{\partial \delta} = (1 - G[v])(p - v) \leq 0 \). Hence, since the feasible set does not change with \( \delta \), if \( \delta_2 \geq \delta_1 \) for all feasible \((v, p)\),

\[
\pi(v, p, \delta_2) \leq \pi(v, p, \delta_1) \leq \pi(v^*(\delta_1), p^*(\delta_1), \delta_1)
\]

Replacing \((v, p)\) with \((v^*(\delta_2), p^*(\delta_2))\), one can see the result.

(iv) Follows from \( v = \frac{p_1 - \delta p_2}{1 - \delta} \geq p_2 \).

**Proof of Theorem 1.** (i) Note that consumers being myopic is equivalent to \( \delta = 0 \) in optimization problem (2). Then from Lemma 2, \( \bar{v}^* \geq \bar{v}^m = p_1^m \) and \( p_2^m \geq p_2^m \). We claim that \( p_2^m > p_2^m \). If \( \bar{v}^* > p_1^m \) and
\( G[\bar{v}^*] = G[p_1^m] \), then facing with myopic consumers, one can change \( p_1^m \) to \( \bar{v}^* \) and earn a higher revenue which is a contradiction with optimality of \( p_1^m \). If \( \bar{v}^* > p_1^m \) and \( G[\bar{v}^*] > G[p_1^m] \), then since the solution in the second period's problem is an interior solution and \( \frac{\partial G[\bar{v}^*] - G[p_1^m]}{\partial p_2} > \frac{\partial G[p_1^m] - G[p_2]}{\partial p_2} \), then \( p_2^* > p_2^m \). Finally, if \( \bar{v}^* = p_1^m \), assume by contradiction that \( p_2^* = p_2^m \). Since from Lemma 2, we know that \( \bar{v}^* \) is nondecreasing in \( \delta \), one has \( \bar{v}^* = p_1^m = \lim_{\delta \to 0} \frac{p_1^m - \delta p_2^m}{1 - \delta} = p_1^s \). Therefore, since \( p_1^m = \frac{p_1^m - \delta p_2^m}{1 - \delta} \), one can see that \( p_1^m = p_2^m \). However, with this the firm receives 0 revenue in the second period which is a contradiction with optimality of \( p_2^m \). Therefore, \( p_2^* > p_2^m \).

(ii), (iii) If \( v \in [p_2^m, p_1^m] \), then in a myopic environment the consumer would purchase in the second period and her utility is given by \( \delta(v - p_2^m) \). From Lemma 2, \( \bar{v}^* \geq p_1^m \). Hence, this consumer would wait for the second period when consumers are strategic and receives utility \( \delta \max(v - p_2^m, 0) \leq \delta(v - p_2^m) \). If furthermore, \( v < p_2^m \), then this consumer cannot afford the item under strategic behavior.

**Proof of Theorem 2.** Using myopic equilibrium prices, one can find that \( \pi^m = \frac{1}{3} \), \( CS^m = \int_0^1 \delta(v - \frac{1}{3})dv + f_1^2 v - \frac{2}{3}dv = \frac{1 + \delta}{18}, \) and \( SW^m = \frac{1 + \delta}{18} + \frac{1}{3} = \frac{7 + \delta}{18} \). Similarly, using the equilibrium prices \( \bar{v}^* = \frac{2 - \delta}{3 - 2\delta} \), \( p_1^s = \frac{(2 - \delta)^2}{6 - 4\delta} \) and \( p_2^s = \frac{2 - \delta}{6 - 4\delta} \), one finds that \( \pi^s = \frac{(2 - \delta)^2}{12 - 8\delta}, CS^s = \int_0^{(2 - \delta)^2} \delta(v - \frac{2 - \delta}{6 - 4\delta})dv + \int_0^{1 - \frac{2 - \delta}{6 - 4\delta}} v - \frac{(2 - \delta)^2}{6 - 4\delta}dv = \frac{(\delta - 2)(5\delta - 2) + 1}{8(3 - 2\delta)^2} \), and \( SW^s = CS^s + (2 - \delta)^2 - \frac{6\delta(\delta + 10) - 36 + 28}{12 - 8\delta} = \frac{6\delta(\delta + 10) - 36 + 28}{8(3 - 2\delta)^2} \). Then one can check that \( CS^s > CS^m, \pi^s < \pi^m \), and \( SW^s < SW^m \), which conclude the result.

**Proof of Lemma 3.** First, note that for any pair of prices a consumer with valuation \( v \) would exert effort if and only if \( \max(v - p_1, \delta(v - p_2) + k) - k > 0 \).

\[
\begin{align*}
\text{Max}_{p_1, v} & \quad (1 - \bar{v})p_1 + \bar{v}^2/4 \\
\text{s.t.} & \quad \bar{v} = \begin{cases} p_1 \quad & k \geq \frac{p_1 \delta}{2} \\ \frac{2(v_1 - k)}{2 - v_1} \quad & \text{otherwise} \end{cases}
\end{align*}
\]

Solving this yields

\[
p_1^k = \begin{cases} \frac{2}{3} & k \geq \frac{\delta}{3} \\
\frac{2k}{3} & \frac{\delta^2 - 2\delta}{2\delta - 6} \leq k < \frac{\delta}{3} \\
\frac{(\delta - 2)^2 - 2(\delta - 1)k}{6 - 4\delta} & 0 \leq k < \frac{\delta^2 - 2\delta}{2\delta - 6} 
\end{cases}
\]

\[
\bar{v}^k = \begin{cases} \frac{2}{3} & k \geq \frac{\delta}{3} \\
\frac{2k}{3} & \frac{\delta^2 - 2\delta}{2\delta - 6} \leq k < \frac{\delta}{3} \\
\frac{\delta + 2k - 2}{2\delta - 3} & 0 \leq k < \frac{\delta^2 - 2\delta}{2\delta - 6} 
\end{cases}
\]

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Proof of Theorem 3. Under strategic behavior, the utility of a consumer with valuation \( v \) is given by

\[
\begin{align*}
u^k(v, k, \delta) &= \begin{cases} 
  v - \frac{\delta}{3} 
  & v \geq \frac{\delta}{3} \\
  \delta(v - \frac{1}{3}) 
  & \frac{\delta}{3} > v \geq \frac{1}{3} \\
  v - \frac{2k}{3} 
  & \frac{2}{3} > v \geq \frac{1}{3} \\
  \delta v - k 
  & \delta v \geq k \\
  v - \frac{(\delta - 2)k(1 - 2\delta k)}{2\delta - 6} - k 
  & \delta^2 = \frac{2\delta - 6}{3} \wedge \delta > \frac{2\delta - 2k}{2\delta - 6} \\
  \delta(v - \frac{2k}{3}) 
  & \delta < \frac{2\delta - 6}{3} \\
\end{cases}
\end{align*}
\]

The result follows then by comparing this utility function with the utility function of a consumer who is myopic under the exogenous model.

Proof of Theorem 4. (i) Under dynamic pricing and endogenous behavior,

\[
\pi^k = \begin{cases}
  \frac{\delta + 1}{2k(2k - 3k)} - \frac{\delta^2 + 4k^2(2k + 1)}{8k(2k - 3k)} & k \geq \frac{\delta}{3} \\
  \frac{\delta^2 - 2\delta + 6}{2k - 6} - \frac{\delta^2 + 4k^2(k + 1)}{8k(2k - 3k)} & 0 \leq k < \frac{\delta^2 - 2\delta + 6}{2k - 6}
\end{cases}
\]

the result follows by piece-wise analysis.

(ii) We have

\[
CS^k = \begin{cases}
  \frac{\delta + 1}{2k(2k - 3k)} - \frac{\delta^2 + 4k^2(2k + 1)}{8k(2k - 3k)} & k \geq \frac{\delta}{3} \\
  \frac{k}{2k - 6} - \frac{\delta^2 + 4k^2(k + 1)}{8k(2k - 3k)} & 0 \leq k < \frac{\delta^2 - 2\delta + 6}{2k - 6}
\end{cases}
\]

For \( \frac{\delta^2 - 2\delta + 6}{2k - 6} \leq k < \frac{\delta}{3} \), \( CS^k = \frac{\delta^2 + 4k^2(2k + 1)}{8k(2k - 3k)} \) and attains its maximum in \( k = \frac{2k - 3k}{6k - 2} \) with the value \( \frac{\delta^2 - 2\delta + 4}{8(3k - 2k)^2} \). Let \( x^* \) be the first root of \( x^3 - 12x^2 + 24x - 12 = 0 \). Then, \( CS^k \) attains its maximum in this region at \( k = \begin{cases}
  \frac{\delta^2 - 2\delta + 6}{2k - 6} & \delta > x^* \\
  0 & \delta \leq x^*
\end{cases} \). One can also check that \( \frac{\delta^2 - 2\delta + 4}{8(3k - 2k)^2} \geq \frac{\delta^2 - 2\delta + 4}{8(3k - 2k)^2} \) for \( \delta \leq x^* \). As such \( CS^k \) is maximized in \( k = \begin{cases}
  \frac{\delta^2 - 2\delta + 6}{2k - 6} & \delta > x^* \\
  0 & \delta \leq x^*
\end{cases} \).

(iii) Combining parts (i) and (ii), we have

\[
SW^k = \begin{cases}
  \frac{\delta^2 + 4k^2(2k + 1)}{8k(2k - 3k)} + \frac{1}{2} \left( \frac{\delta^2 - 2\delta + 6}{2k - 6} \right)^2 & k \geq \frac{\delta}{3} \\
  \frac{\delta^2 - 2\delta + 6}{2k - 6} \leq k < \frac{\delta}{3} \\
  \frac{\delta^2 - 2\delta + 6}{2k - 6} & 0 \leq k < \frac{\delta^2 - 2\delta + 6}{2k - 6}
\end{cases}
\]

For \( 0 \leq k < \frac{\delta^2 - 2\delta + 6}{2k - 6} \), \( dSW^k = -\frac{\delta^2 - 4\delta + 12k + 16k^2 + 28}{2k - 6} \). Also \( SW^k \) is constant in \( k \) for \( k \geq \frac{\delta}{3} \). The result then follows by noting that \( SW^k \) is continuous in \( k \).

Proof of Lemma 4. Similar to the proof of Lemma 3, one needs to solve the following optimization problem:

\[
\begin{align*}
\max_{p_1, p_2, \bar{v}} & \quad (1 - \bar{v})p_1 + (\bar{v} - p_2)p_2 \\
\text{s.t.} & \quad \bar{v} = \max(p_1, \frac{p_1 - \delta p_2 - k}{1 - \delta})
\end{align*}
\]

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The result is that
\[ p^c_1 = \begin{cases} \frac{1}{3} + \frac{k}{25} & k \geq \frac{\delta}{3} \\ \frac{\delta^2 - \delta}{3} & \frac{\delta^2 - \delta}{3} \leq k < \frac{\delta}{3} \end{cases} \]
\[ p^c_2 = \begin{cases} \frac{1}{3} - \frac{k}{25} & k \geq \frac{\delta}{3} \\ \frac{\delta^2 - \delta}{3} & \frac{\delta^2 - \delta}{3} \leq k < \frac{\delta}{3} \end{cases} \]
\[ \bar{d}^c = \begin{cases} \frac{1}{3} + \frac{k}{25} & k \geq \frac{\delta}{3} \\ \frac{\delta^2 - \delta}{3} & \frac{\delta^2 - \delta}{3} \leq k < \frac{\delta}{3} \end{cases} \]

**Proof of Theorem 5.** From the analysis of dynamic pricing and price commitment, we have, for the former,

\[ \pi^k = \begin{cases} \frac{1}{3} + \frac{k_d(2\delta - 3k_d)}{\delta^2 + 4(k_d^2 + k_d + 1) - 4\delta(k_d + 1)} & k_d \geq \frac{\delta}{3} \\ \frac{\delta^2 - \delta}{3} & \frac{\delta^2 - \delta}{3} \leq k_d < \frac{\delta}{3} \end{cases} \]

and \[ \pi^c = \begin{cases} \frac{1}{3} + \frac{(\delta - k_c)(\delta + 3k_c)}{\delta^2 + 4(k_c^2 + k_c + 1) - 4\delta(k_c + 1)} & k_c \geq \frac{\delta}{3} \\ \frac{\delta^2 - \delta}{3} & \frac{\delta^2 - \delta}{3} \leq k_c < \frac{\delta}{3} \end{cases} \]


(i) If \( k_c = k_d = k \),

\[ \pi^c - \pi^k = \begin{cases} 0 & \delta \leq k \\ \frac{2\delta - d^2}{6 - 23} & \frac{2\delta - d^2}{6 - 23} \leq k < \frac{\delta}{3} \\ \frac{\delta - \delta^2}{3} & \frac{\delta - \delta^2}{3} \leq k < \frac{\delta}{3} \end{cases} \]

One can perform piece-wise analysis to find the result.

(ii) Observe that profit is strictly increasing and continuous in \( k_d \) or \( k_c \) in both cases. Let \( \pi^i(\delta, k) \) be the firm’s profit under pricing mechanism \( i \in \{ s, c \} \), when consumers discount factor and cost of strategic behavior are \( \delta \) and \( k \), respectively. Note that from Part (i), for any fixed \( k_c < \frac{\delta}{3} \), \( \pi^c(\delta, k_c) < \pi^c(\delta, k_c) \). In addition \( \pi^i(\delta, \frac{\delta}{3}) = \pi^c(\delta, \frac{\delta}{3}) > \pi^c(\delta, k_c) \). Therefore, from Intermediate Value Theorem, there exists some \( \tilde{k}_d(k_c, \delta), k_c = \tilde{k}_d(k_c, \delta) < \frac{\delta}{3} \) such that \( \pi^i(\delta, \tilde{k}_d(k_c, \delta)) = \pi^c(\delta, k_c) \). Since \( \pi^i(\delta, k) \) is increasing in \( k \), for \( k_d \geq \tilde{k}_d(k_c, \delta), \pi^i(\delta, k_d) \geq \pi^i(\delta, \tilde{k}_d(k_c, \delta)) = \pi^c(\delta, k_c) \). The uniqueness of \( \tilde{k}_d(k_c, \delta) \) follows from monotonicity of \( \pi^i(\delta, k) \) in \( k \).

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