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# Marketing of Vice Goods: A Strategic Analysis of the Package Size Decision

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Consumers are often unable to resist the temptation of overconsuming certain products such as cookies, crackers, soft drinks, alcohol, etc. To control their consumption, some consumers buy small packages or abstain from purchasing the product altogether. Other consumers, however, still purchase large packages and overconsume. From a strategic perspective, firms have the option of introducing small packages or only offering large packages. We use the literature on hyperbolic discounting to model consumers' self-control problems and examine conditions under which firms will offer small packages to help consumers combat their self-control problem, and how this offering in turn affects prices, profits, consumer, and social welfare. Our results show that introducing small packages can increase firms' profits only when a small fraction of consumers have overconsumption problems or when small packages can bring in new customers. Additionally, we find that competition can sometimes reduce the incentives for firms to introduce small packages. This is particularly true when a large fraction of consumers is attracted to small packages. We also find that firms' profits can sometimes decrease if they produce healthier alternatives of their goods. Our analysis of consumer welfare reveals that small packages enhance consumer and social welfare, even though they sometimes increase the consumption of vice goods.

*Key words:* game theory; hyperbolic discounting; behavioral economics

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## 1. Introduction

Consumers are increasingly becoming more health conscious. Surveys indicate that at any given time, two-thirds of the U.S. population is dieting to lose weight (Cochran and Tessler 1996). Such efforts are complicated by the fact that consumers are tempted by products such as potato chips, cookies, crackers, ice cream, alcohol, caffeinated products, and soft drinks. Although moderate consumption of such products is not harmful, excessive consumption has long-term harmful effects, ranging from increased weight, high blood pressure, and diabetes (see, for example, Beulens et al. 2006, Vartanian et al. 2007). Consumers, however, often find it difficult to resist the temptation of overeating many such goods, even though they later regret such behavior. Many consumers recognize their inability to resist the temptation of these vice goods at the consumption occasions, and they therefore try to take corrective actions at the purchasing stage by rationing their purchases (Werthenbroch 1998).<sup>1</sup> For example, some consumers choose not to buy soft drinks, or they buy only

small packages of vice goods. In response to this trend, firms offer healthier alternatives such as low-fat snacks and also sell products in small packages. For example, in 2004, Kraft introduced Oreos and Chips Ahoy cookies in 100-calorie packs and achieved \$100 million sales in the very first year (Barrett 2004). Currently, all major manufacturers of snacks offer 100-calorie products (Goff 2008).<sup>2</sup>

Previous research in consumer behavior has examined how small packages affect consumption. Wansink (1996) finds that large package sizes can increase usage. Other studies have also shown that portion sizes positively affect consumption (see, for example, Geier et al. 2006, Rolls et al. 2002). In a more recent study, Scott et al. (2008) find that small package sizes can lead to increased consumption by dieters because they perceive smaller packages to be healthier. Werthenbroch (1998) shows that the consumer's desire to regulate the consumption of vice goods can lead him or her to prefer smaller packages more strongly, because it enables one to control inventory

<sup>1</sup> Vice goods are defined as those that consumers are likely to overconsume at the consumption stage, although they would later regret doing so (see Werthenbroch 1998 for a similar conceptualization).

<sup>2</sup> The idea of offering small packages has also influenced menu size decisions by restaurants such as TGIFriday's, which has introduced its "Right Portion, Right Price" menu with smaller portion sizes.

and therefore consumption. His results show that consumers of such vice goods are less price sensitive for small package sizes. Although this research sheds light on consumption behavior, there is little research that has examined the firm-level strategic implications of introducing small package sizes for vice goods.<sup>3</sup>

From a firm's perspective, there are several issues about package sizes that are important to understand. First, when would firms find it beneficial to introduce products in small packages? Because vice goods are often overconsumed when bought in larger quantities, selling them in smaller quantities could lead to decreased demand. However, firms could potentially compensate for lost demand by charging premium prices for small packages. In fact, a study by the Center for Science in the Public Interest finds that price premium for 100-calorie products over large packages could be as high as 279%.<sup>4</sup> This raises two questions. First, why would consumers be willing to pay such price premiums when they could easily buy the larger package and dispose of the excess quantity while still paying less? Second, can firms sustain such price premiums in a competitive setting? Furthermore, it is also useful to understand how the vice nature of these goods and the degree of consumers' self-control problems affect the pricing and sales of such goods.

From a consumer welfare perspective, it is important to examine how small packages affect consumer surplus. Small packages could enable some consumers to consume less but could also entice some consumers to buy a product that they would not otherwise. Furthermore, consumers may be forced to pay higher prices for smaller packages. Wansink and Huckabee (2005) suggest that firms should

voluntarily offer small package sizes to reduce consumption, whereas others have suggested measures such as taxes to reduce the consumption of vice goods (see, for example, Jacobson and Brownell 2000). However, it is not clear whether and when firms in a competitive setting will voluntarily offer small packages and whether such introductions would necessarily improve consumer welfare.

Despite the importance of these questions, there is little research that has addressed these issues. The purpose of this paper is to develop an analytical model to examine these issues.<sup>5</sup> More generally, we develop an analytical framework that can be used to study firm-level decisions in contexts where consumers have problems of overconsumption. In our model, consumers shop for a product that can be consumed over two periods. Consumers could consume up to two units in each period. To model the vice nature of the good, we assume that moderate consumption of up to one unit of the good is not harmful, whereas consumption of two units leads to harm that is experienced in later periods. We refer to the consumption of two units in any period as overconsumption.<sup>6</sup> We use the literature on hyperbolic discounting to model consumers' self-control problem. Hyperbolic discounting leads to a discrepancy between consumer's utility in the purchasing stage and the consumption phase.<sup>7</sup> In particular, some consumers are likely to overconsume, and they can potentially correct for this at the purchasing stage by either buying small packages (if available) or abstaining from buying. We consider a duopoly in which firms can either sell only a large package consisting of two units of a good or introduce a small package consisting of one unit of the good. Using this framework, we examine whether and when firms would introduce small packages. We also examine the

<sup>3</sup> There is also literature in marketing and economics that deals with quantity discounts and is tangentially related to our paper. In marketing, quantity discounts have been studied as a means of channel coordination and for achieving better price discrimination among consumers (see, for example, Jeuland and Shugan 1983, Oi 1971, Subramaniam and Gal-Or 2009). In contrast to this research, our results are driven by consumers' self-control problems, and absent those in our framework, firms would not offer small packages. Thus, the context that we are examining and our results are quite distinct from those obtained in the literature on quantity discounts. Another stream of research that is related to our paper examines price discrimination in a competitive setting. For example, there is research that examines how firms' ability to price discriminate because of their ability to observe purchase history affects price competition (see, for example, Villas-Boas 1999; for a review of this literature, see Fudenberg and Villas-Boas 2006, Stole 2007). Koenigsberg et al. (2010) study package design in the context of goods that deteriorate over time. In their context, small packages can reduce waste and allow consumers to match their purchases with desired consumption, thereby increasing consumers' willingness to pay for small packages. In contrast, we study how small packages can enable price discrimination in the presence of consumers' self-control problems.

<sup>4</sup> See Center for Science in the Public Interest (2007).

<sup>5</sup> In a recent paper, Dobson and Gerstner (2010) examine a related question as to whether firms that offer regular-sized food should supersize foods. In their formulation, supersizing can help price discriminate among the consumers who can exert self-control and those who cannot. They find that a monopolist may find it profitable to supersize foods because this could lead to market expansion and better price discrimination between the two segments of consumers. However, in their formulation the two segments of consumers and their valuations are exogenously specified. Furthermore, they do not consider the impact of competition on firm behavior. We study the question of whether firms should offer small packages and develop a model in which the segments with self-control problems are endogenously determined. Furthermore, we study the impact of competition.

<sup>6</sup> This terminology is consistent with the general notion that consumption at a rate that leads to bad future outcomes such as excess weight is considered overconsumption.

<sup>7</sup> The discrepancy between consumer's preference at the purchasing and consumption stages could also arise because of other reasons, such as uncertainty about future utility (see Guo 2006).

implications of small packages on firms' prices and consumer and social welfare.

We find several interesting results. Our results show that the profitability of introducing small packages depends on two critical factors: (1) the proportion of consumers who are likely to overconsume the product and would find small packages attractive, and (2) the presence of consumers who abstain from buying rather than overconsume. We find that when the market is saturated, offering small packages is only beneficial if, before the introduction of small packages, only a small proportion of the consumers overconsume the product. In this case, firms can benefit by offering consumers who are relatively less price sensitive small packages at a premium, and therefore these firms practice better price discrimination. Interestingly, in this scenario, our results show that the vice nature of the good can actually boost firms' profits. In other words, with a strategy of offering small packages, firms selling vice goods would make higher profits than firms selling normal goods. This is because the vice nature of the good enables firms to charge a premium price for small packages because they enable consumers to eliminate overconsumption.

Our results, however, show that the ability of firms to extract surplus from consumers can become severely limited when absent small packages, a large proportion of consumers overconsume. Such situations can arise when consumers have relatively high valuation for the products and also have a high degree of self-control problems, or when the products are relatively undifferentiated and competition is more intense. We show that in such cases, firms' prices and profits decline with the introduction of small packages. In this case, firms might not introduce small packages, despite the fact that a large proportion of consumers would want small packages because the problem of overconsumption is more prevalent. Our results suggest that in such situations, firms' profits could improve if they could make overconsumption less harmful. Thus, strategies such as producing healthy, low-calorie products rather than offering small packages can be more profitable. We find that if some consumers abstain from buying the product to avoid overconsumption, then firms could benefit by introducing small packages, even in situations when a large proportion of consumers choose small packages. This is because small packages in this case can increase market size. Interestingly, overall consumption of the vice goods among the consumers sometimes goes up with the introduction of small packages. Despite this increase, however, consumer welfare improves with the introduction of small packages.

The paper adds to the literature that examines strategies that consumers, firms, and public policy

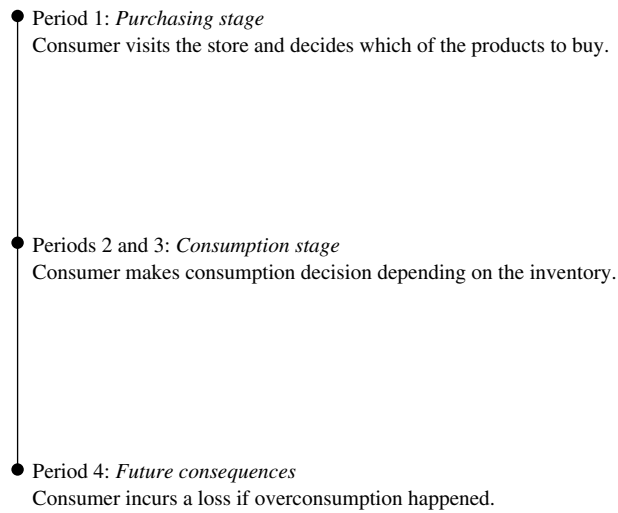
makers can use to address the increasing obesity rates in United States (see, for example, Seiders and Petty 2004, Wansink and Huckabee 2005). Although much of this research has focused on understanding consumer behavior, there is little research that has addressed firms' incentives to reduce consumption. This paper addresses these issues. Furthermore, this paper develops a framework that can be used to address related issues such as the impact of healthier alternatives and government regulations, such as taxation and advertising restrictions, on the nature of competition, firms' profits, and social welfare.

This paper also adds to the growing literature in marketing and economics that has modeled self-control problems using hyperbolic discounting (for example, see Laibson 1997, DellaVigna and Malmendier 2004, Gilpatric 2009, Jain 2009). Most of these studies, however, have only examined consumer behavior implications of hyperbolic discounting or its firm-level implications in a monopoly setting. We extend this literature by examining how consumers' self-control problems can affect competition. This paper is more broadly related to the growing literature in marketing, which tries to enrich standard economic models by incorporating psychological and sociological realism in these models (see, for example, Carpenter and Nakamoto 1990, Wernerfelt 1995, Amaldoss and Jain 2005, Syam et al. 2008, Villas-Boas 2009). The remainder of this paper is organized as follows. In §2, we develop our model. In §§3, 4, and 5, we present the model analysis and results. We present extensions of the base model in §6. In §7, we conclude our paper with managerial implications and directions for future research.

## 2. Model

We consider the case where there are two firms in the market selling a vice good to the consumers. Figure 1 represents the decisions that each consumer makes over three periods. In period 1, each consumer undertakes a shopping trip to a store to purchase the good. In periods 2 and 3, the consumer decides whether and how much to consume the product, given the inventory of the product. Note that we are assuming that the cost of undertaking a shopping trip before each consumption period is large. This assumption is used to capture the empirical observation that the number of purchase occasions is fewer than the number of consumption occasions. For example, many consumers undertake shopping trips once a week to the grocery store and have multiple opportunities to consume the products during the week. An alternate assumption would be to allow the consumers the option of purchasing before each consumption occasion. We find that the basic nature of the results hold even in this alternate formulation.

**Figure 1** Sequence of Consumer Decisions



We assume that each consumer could consume up to two units of the good in any given period. Consumers have heterogeneous product preferences, and we model this by assuming that consumers are distributed on a Hotelling line with the firms located at 0 and 1 (Hotelling 1929). The utility that a consumer at  $\theta$  derives from consumption of firm 1's product consists of an immediate benefit of  $v_1(\theta)$  per unit consumed, which is given by  $(r - t\theta)$ , where  $t$  is a parameter that represents the disutility that the consumer experiences from not consuming his ideal product. This term can also be viewed as the level of differentiation between the products (see, for example, Iyer and Soberman 2000, Amaldoss and Jain 2005).<sup>8</sup> The benefit from consuming firm 2's product is  $v_2(\theta) = r - t(1 - \theta)$ . We assume that  $\theta$  is distributed according to a log-concave continuous distribution function  $f(\cdot)$ , with cumulative distribution  $F(\cdot)$ . Several distributions such as the normal, Weibull, uniform, exponential, and numerous families of beta and gamma distributions are log-concave. Furthermore, the truncated versions of these distributions are also log-concave (see, for example, Bagnoli and Bergstrom 2005). We focus on the case of symmetric firms and therefore assume that  $f(\cdot)$  is symmetric around  $\frac{1}{2}$ ; i.e.,  $f(x + \frac{1}{2}) = f(\frac{1}{2} - x) \forall x \in (0, \frac{1}{2})$ . This assumption allows us to model symmetric firms while still allowing for a fairly general distribution.<sup>9</sup>

To capture the vice good aspect of the product, we assume that overconsumption leads to delayed harm.

One can define overconsumption in terms of the *rate* of consumption or the *total* consumption across the two periods. We use the literature that argues that a moderate *rate* of consumption of caffeine, alcohol, soft drinks, etc., is not harmful. However, excessive consumption in any given period is harmful (see, for example, Beulens et al. 2006, Vartanian et al. 2007). For example, excessive consumption of caffeine (which is present in most soft drinks) on a given day can make an individual irritable, increase heart rate, etc., but does not have these adverse effects if it is consumed at a moderate rate over a period of several days. Similarly, there is evidence that spreading calorie consumption over multiple periods is better for one's health than consuming at one time (see, for example, Jenkins et al. 1995, Barba et al. 2006). To model this, we assume that whereas the first unit consumed in any time period has no negative consequences, the second unit leads to delayed harm of  $h$ .<sup>10</sup> The harm  $h$  is the negative consequence of consuming a vice good and is incurred in time period 4. This harm could be physiological or psychological, such as feelings of guilt. We assume that  $0 < h < 2r$ , where the condition  $h < 2r$  allows for the possibility that some consumers could overconsume. If  $h$  is small, the long-term harm is small, but if  $h$  is large, then a rational consumer should never consume two units at a time. As we will see later, our formulation captures the notion that a consumer's overconsumption across multiple periods is related to his or her inability to consume in moderation in any given period. Indeed, in our formulation, some consumers not only consume more in any given period but also have a higher *total* consumption. An alternate formulation would assume that only the total consumption over the two periods matter, but consumers can costlessly visit the store before the beginning of each period. We find that the basic nature of our results would continue to hold even in this alternate formulation.

With this setup, consider a rational consumer's consumption decision. The consumer decides in periods 2 and 3 how much to consume given the available inventory. Consider the case when a consumer has an inventory of two units at the beginning of period 2. In this case, the consumer could choose moderate consumption by consuming one unit in each period or overconsume by consuming both units in period 2. If  $\delta$  is the per-period discount factor, then this consumer will consume both units in period 2 only if

$$2v(\theta) - \delta^2 h > (1 + \delta)v(\theta). \quad (1)$$

<sup>8</sup> To see this, note that as  $t$  increases, a consumer's strength of preference for the product that is closer to his ideal point increases. Therefore, as  $t$  increases, consumers find it more difficult to switch from their preferred product. In other words, as  $t$  increases, firms become more differentiated.

<sup>9</sup> The assumption does, however, rule out certain log-concave distributions such as exponential and gamma distributions, which are inherently asymmetric.

<sup>10</sup> A more general formulation would assume that the delayed costs are a convex function of the number of units consumed at a time and the total number consumed. Our assumption can be viewed as an approximation of such a convex function.

This implies that this consumer will consume both units in period 2 only if

$$v(\theta) > \frac{h\delta^2}{1-\delta}. \quad (2)$$

Note that if  $\delta \rightarrow 1$ , then this inequality will never be satisfied, and the consumer will always consume in moderation. Also, note that the consumer in period 1 will also want moderate consumption if and only if he finds moderate consumption beneficial in period 2. In other words, with little discounting, consumers with inventory of two units will consume in moderation, and furthermore, there will be no discrepancy between consumers' desire for moderate consumption and actual behavior. This is, of course, not what we observe empirically. We are interested in situations in which consumers are not able to ration consumption appropriately because they have self-control problems. To model self-control problems, we assume that consumers have present-biased preferences. This approach is widely used to model self-control problems (e.g., Laibson 1997, O'Donoghue and Rabin 1999, Carrillo and Mariotti 2000, DellaVigna and Malmendier 2004, Machado and Sinha 2007, Gilpatric 2009).<sup>11</sup> In particular, the discount function is given by

$$D(\tau) = \begin{cases} 1 & \text{if } \tau = 0, \\ \beta\delta^\tau & \text{otherwise,} \end{cases} \quad (3)$$

where  $\delta$  is the usual exponential discount factor, and  $\beta$  is the quasi-hyperbolic discounting parameter where  $0 < \beta < 1$ . Note that in this formulation, the consumer's discounting depends on the time at which he makes the decision. To focus on situations in which, absent self-control problems, the consumer will always consume in moderation if he has two units available, we assume that  $\delta = 1$ . This assumption is reasonable because the time between purchasing and consuming is only a few days and is also consistent with most of the prior literature on self-control, where this is a common assumption (see, for example, O'Donoghue and Rabin 1999, Gilpatric 2009).

### 3. Analysis of the Consumer's Decision

In our paper, firms decide on the package size and then decide on prices. Next, the consumers make their purchasing decisions in period 1, which is then followed by the consumers' consumption decisions in

periods 2 and 3. This sequential decision of packaging and pricing is appropriate because packaging decisions are less flexible, and prices are more easier to change. As usual, we will solve the game backwards. Note that consumers in periods 1–3 have different preferences. Thus, to make their decisions, these consumers must predict what their future selves would do. We assume that consumers form rational expectations about their behavior in the consumption stage. This assumption is consistent with prior research (see, for example, Laibson 1997, O'Donoghue and Rabin 2000). Also, in our case, the consumer only needs to correctly anticipate a binary decision, which is not too onerous.<sup>12</sup> However, casual observation suggests that sometimes consumers may not perfectly anticipate their future actions (see O'Donoghue and Rabin 2003 for a discussion). In §6.1, we discuss the implications of this case.

#### 3.1. Consumption Decision

We will first consider the case when firms offer a large package with two units and later consider the case when firms also offer a single-unit small package. We will analyze the consumption and purchasing decision from the perspective of firm 1's product. The analysis for firm 2 is analogous. Before proceeding, we need to decide the residual value of leftover product at the end of period 3. We will make the conservative assumption that the residual value is zero.<sup>13</sup> Details of the analysis are presented in the electronic companion, available as part of the online version that can be found at <http://mktsci.journal.informs.org/>.

**3.1.1. Consumer in Period 3.** First, consider the case when the firm offers only large packages. The consumer can consume at most two units or may choose to consume one unit or nothing. The consumer prefers to consume two units rather than one if

$$2(r - t\theta) - \beta h > r - t\theta, \quad (4)$$

where we break ties in favor of lower consumption. This equation reduces to the condition that

$$\theta < \frac{r}{t} - \frac{\beta h}{t} = \tilde{\theta}_1. \quad (5)$$

<sup>12</sup> As we will see later, this assumption is consistent with the empirically observed phenomenon of consumer rationing. In fact, absent the realization that he has self-control problems, the consumer will not ration purchases or forgo consumption. Both of these strategies have been empirically observed, thus lending some credence to the assumption that consumers anticipate their future actions and try to take corrective actions in the buying stage.

<sup>13</sup> We could also assume that the residual value is a fraction of the value from consumption in future periods. Such a formulation would only strengthen our results. In any case, there are no leftovers in equilibrium.

<sup>11</sup> There are also other approaches for modeling self-control problems. See, for example, Thaler and Shefrin (1981), Gul and Pesendorfer (2001), and Fudenberg and Levine (2006).

The consumer would consume something rather than nothing if  $\theta < r/t = \theta_1^{b0}$ .

Now, consider the case when the firm also offers small packages. We assume that a unit of product in a small package provides the same utility as a unit in a large package. In this case, note that two small packages are equivalent to a large package.<sup>14</sup> With this assumption, the analysis with small packages is similar to the case when the firm only offers large packages, because the consumer can consume at most two units. The consumer will consume two units of product 1, as long as  $\theta < \tilde{\theta}_1$ , and would consume a single unit for  $\theta \in [\theta_1, \theta_1^{b0})$ .

**3.1.2. Consumer in Period 2.** Now consider the consumer's decision in period 2. If the consumer consumes  $x$  units in period 2 and  $y$  units in period 3, we will denote this consumption pattern by  $(x, y)$ . If  $\theta < \theta_1^{b0}$ , then we know that the third-period consumer would consume at least one unit, if possible. If  $\theta < \theta_1^{b0}$  and the consumer has two units of inventory at the beginning of period 2, then he can decide to consume two units, leading to a consumption pattern  $(2, 0)$ , or a single unit, which would lead to consumption pattern  $(1, 1)$ . The consumer prefers  $(2, 0)$  to  $(1, 1)$  if

$$2(r - t\theta) - \beta h > (1 + \beta)(r - t\theta), \quad (6)$$

which reduces to the condition

$$\theta < \frac{r}{t} - \frac{\beta}{1 - \beta} \cdot \frac{h}{t} = \theta_1. \quad (7)$$

The term  $\theta_1$  turns out to be critical in our analysis, and therefore we discuss it further. Note that for  $\theta_1 > 0$ , we require that  $\beta < r/(r + h)$ . It is important to understand how  $\theta_1$  varies with the parameters of our model. First, we observe that  $\theta_1$  is likely to be higher as  $r$  increases. This is reasonable because the consumer is less likely to be able to consume in moderation if the consumer derives a relatively high valuation from consumption. Also, as  $\beta$  increases, i.e., the self-control problem decreases,  $\theta_1$  decreases. Furthermore, when firms are more differentiated, i.e.,  $t$  increases, fewer consumers have overconsumption problems. Furthermore, as is intuitive,  $\theta_1$  decreases as

the future harm from overconsumption increases. It is also useful to note that  $\theta_1 < \tilde{\theta}_1$ . Analogous to  $\theta_1$ , we can define  $\theta_2$  for product 2 as

$$\theta_2 = 1 - \frac{r}{t} + \frac{\beta}{1 - \beta} \cdot \frac{h}{t} = 1 - \theta_1. \quad (8)$$

Thus, if the consumer has two units of inventory at the beginning of period 2, he will consume both units if  $\theta < \theta_1$  and consume one unit in each period if  $\theta \in (\theta_1, \theta_1^{b0})$ .

Now consider the case when the consumer has bought two large packages and therefore has four units available for consumption. If  $\theta > \theta_1^{b0}$ , then the third-period consumer does not consume any unit of product 1. Therefore, if  $\theta > \theta_1^{b0}$ , then the second-period consumer has a choice between  $(2, 0)$ ,  $(1, 0)$ , and  $(0, 0)$ . In this case, it is easy to see that the consumer prefers to consume nothing. When  $\theta < \tilde{\theta}_1$ , the consumer knows that the third-period consumer would consume two units. By earlier analysis, we know that the consumer would prefer  $(2, 2)$  over  $(1, 2)$  as long as  $\theta < \tilde{\theta}_1$ . Therefore, if  $\theta < \tilde{\theta}_1$ , the consumer would prefer to consume two units, and the consumption pattern is  $(2, 2)$ . Finally, consider the case when  $\theta \in [\theta_1, \theta_1^{b0})$ . In this case, the third-period consumer would consume a single unit, and therefore the choice for the second-period consumer is between  $(2, 1)$  or  $(1, 1)$ . Since  $\theta > \tilde{\theta}_1$ , the consumer prefers  $(1, 1)$ . The analysis therefore shows that for the region  $[\theta_1, \tilde{\theta}_1)$ , the consumer consumes in moderation, i.e.,  $(1, 1)$ , if the inventory in period 2 is two units but overconsumes, i.e., consumes  $(2, 2)$ , if the inventory is four units.

Now consider the case when the firm also offers small packages. With the introduction of small packages, the only new cases that we need to analyze are when the consumer in period 2 has either one unit or three units of the product. If the consumer has one unit of the product, he will consume the product as long as  $\theta < \theta_1^{b0}$ . If the consumer has three units available, then he has to decide whether to consume two units in period 2 and one unit in period 3, or to consume only one unit in each period. The analysis is similar and is presented in the electronic companion. The analysis shows that the consumer with an inventory of three units will have the consumption pattern  $(2, 1)$  if  $\theta < \tilde{\theta}_1$  and  $(1, 1)$  if  $\theta \in [\tilde{\theta}_1, \theta_1^{b0})$ . The analysis therefore shows that for consumers in the region  $(\theta_1, \tilde{\theta}_1)$ , we can observe consumption patterns of  $(1, 1)$ ,  $(2, 1)$ , or  $(2, 2)$ , depending on the inventory at the beginning of period 2. It is also important to note that in our framework, consumers who overconsume and consumers who do not are determined endogenously. Furthermore, note that whether a consumer overconsumes is dependent not only on the self-control parameter ( $\beta$ ) but also on the consumer's valuation of the product and the degree of competition.

<sup>14</sup> It is possible that some consumers may find small packages to be attractive because they are more convenient or because they retain freshness longer. To focus on the role of small packages in reducing consumption, we will assume that consumers perceive both package sizes to provide equal per-unit utility. There is also some research that suggests that consumers will consume less if they have to open small packages. This is possibly due to the psychological cost of opening the package or the fact that small packages help consumers monitor consumption (Wansink 2004). We can show that our results would continue to hold even when we allow for these possibilities. Details are available from the author on request.

### 3.2. Purchasing Decision

Now consider period 1, which is the purchasing stage. We will analyze the purchasing decision as if firm 1 is a monopolist. The analysis when both firms are present is similar except that we will need to identify the marginal consumer who is indifferent between buying the two products. Consider the case when the firm only sells large packages. The price that firm 1 charges per unit is given by  $p_1^l$ . Suppose  $\theta < \theta_1$ . In this case, if the consumer buys a large package, then the consumption pattern is  $(2, 0)$ . On the other hand, if the consumer purchases two large packages, then the consumption pattern is  $(2, 2)$ . It is easy to see that if the consumer gets positive utility from the consumption of a large package, then he will purchase two large packages for  $\theta < \theta_1$ . Thus, we see that the inability to consume in moderation in any given period leads to overconsumption in each period and higher total consumption. Now consider the case when  $\theta > \theta_1$ . We know from the analysis of period 2 consumer that the consumption pattern in this situation is  $(1, 1)$  or  $(0, 0)$ . Therefore, the consumer will buy at most a single large package of firm 1's product when  $\theta > \theta_1$ .

Finally, consider the case when  $\theta \in [\theta_1, \tilde{\theta}_1]$ . In this case, we know that the consumer's consumption pattern would be  $(2, 2)$  if he buys two large packages and  $(1, 1)$  if he purchases one large package. The consumer in the first stage can control the level of consumption by his purchasing decision. The consumer prefers to buy two large packages rather than a single large package if

$$2\beta(r - t\theta) - 2p_1^l < 4\beta(r - t\theta) - 2\beta h - 4p_1^l, \quad (9)$$

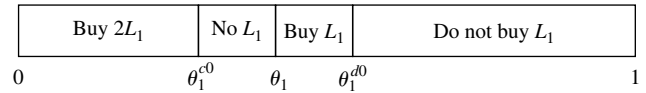
which reduces to the condition that  $\theta < \theta_{1a}$ , where

$$\theta_{1a} = \frac{r}{t} - \frac{h}{t} - \frac{p_1^l}{\beta t}. \quad (10)$$

Therefore, if the firm only offers large packages, and the consumer prefers to buy rather than not buy, then the consumer prefers two large packages over a single large package for  $\theta \in [0, \theta_{1b})$ , where  $\theta_{1b} = \max(\theta_1, \theta_{1a})$ . It is useful to note that if  $\beta < \frac{1}{2}$ , then  $\theta_{1b} = \theta_1$ . This implies that if  $\beta < \frac{1}{2}$ , no consumer with  $\theta > \theta_1$  overconsumes.<sup>15</sup>

<sup>15</sup> Note that we have followed convention and defined overconsumption in terms of rate of consumption that leads to harmful future consequences. Alternatively, we could define overconsumption in terms of the preference of consumer in the purchasing stage. Under this definition, a consumer in the region  $(0, \theta_{1a})$  rationally consumes at a high rate. However, even with this definition, some consumers in the region  $(\theta_{1a}, \theta_1)$  who purchase two large packages consume at a higher rate than they would like. This is because these consumers are not able to control consumption in periods 2 and 3. These are the consumers who are likely to be attracted to small packages.

Figure 2 Market Is Not Fully Covered, and Firm 1 Is a Monopolist

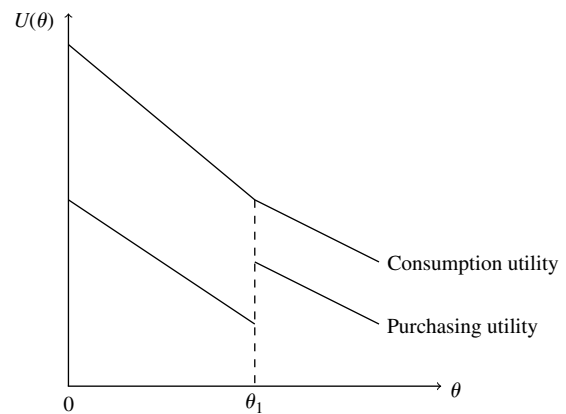


Note. Large packages only.

Now, consider the possibility that some consumers may prefer not to consume. The utility from buying two large packages, when the consumption pattern is  $(2, 2)$ , is positive only if  $\theta < \theta_1^{c0} = r/t - h/(2t) - p_1^l/(\beta t)$ . On the other hand, if the consumer purchases a large package and the consumption pattern is  $(1, 1)$ , then the consumer finds it profitable to purchase a large package only if  $\theta < \theta_1^{d0} = r/t - p_1^l/(\beta t)$ , where it is easy to see that  $\theta_1^{d0} > \theta_1^{c0}$ . Note that it is possible that  $\theta_1^{c0} < \theta_1 < \theta_1^{d0}$ . This leads to the purchase pattern shown in Figure 2. In this case, the consumer in the region  $(\theta_1^{c0}, \theta_1)$  does not buy the good, whereas consumers in the region  $(\theta_1, \theta_1^{d0})$  purchase a single large package. In other words, although the instantaneous utility from consumption is decreasing in  $\theta$  for consumers with  $\theta \in (\theta_1^{c0}, \theta_1)$ , the purchasing utility need not monotonically decrease with  $\theta$ . This is because the utility function for purchasing is discontinuous at  $\theta = \theta_1$  and in particular has an upward jump at  $\theta_1$ , because the consumers for  $\theta > \theta_1$  do not overconsume and thus do not incur the long term cost  $h$ . At the consumption stage, however, preferences are monotonically decreasing in  $\theta$  (see Figure 3). This implies that the preference ordering at the consumption stage is not preserved at the purchasing stage.

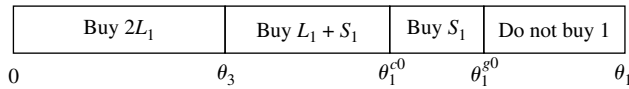
Now consider the case when the firm also offers small packages. In this case, it turns out that the introduction of small packages only affects the decision of consumers when  $\theta_1 > \theta_{1a}$  and only for consumers with  $\theta \in [0, \theta_1)$  (see the electronic companion for details). This is intuitive because the consumers in region  $\theta > \theta_1$  can exert self-control even without the small packages. Some consumers in the region  $(0, \theta_1)$

Figure 3 Utility from a Large Package of Product 1 with Inventory = 2





**Figure 4** Market Is Not Fully Covered, and Firm 1 Is a Monopolist



Note. Small and large packages.

purchase small packages to reduce their total consumption and achieve a consumption pattern (2, 1). On the other hand, the introduction of small packages could also lead to some consumers (such as those in the region  $(\theta_1^{c0}, \theta_1^{s0})$  in Figure 4) to buy a small package. Therefore, small packages affect sales in two ways. First, small packages could reduce total sales because some consumers who were consuming two large packages now consume one fewer unit. Second, small packages can increase consumption by those who choose to abstain from purchasing when only large packages are available.

#### 4. Firm-Level Analysis: Monopoly

Now, we will analyze the firm's pricing and packaging decisions, given the decisions of consumers in periods 1–3. We will first analyze the benchmark case of a monopoly. We will then analyze the case when there are two firms in the market. This will allow us to more clearly understand the implications of competition on firms' package size decisions.

First, consider the case when the firm only offers a large package size and all consumers with  $\theta < \theta_1$  purchase. Note that this case includes the situation when all consumers from  $[\theta_1, 1]$  buy the product, i.e., the market is fully covered, and the situation when some consumers in the region  $[\theta_1, 1]$  do not buy. From our earlier analysis, we know that small packages only affect the decision of consumers in the region  $[0, \theta_1)$ . Furthermore, if all consumers are purchasing in the region  $[0, \theta_1)$ , then these consumers must be purchasing two large packages. The introduction of small packages could potentially entice some consumers to switch to buying a small package. In other words, some consumers now buy one large and one small package (i.e.,  $L_1 + S_1$ ) rather than two large packages of firm 1's product. In this case, we find that as long as  $\beta < \frac{1}{2}$ , the monopolist will introduce a small package.<sup>16</sup> The intuition is that for small  $\beta$ , the monopolist can more than compensate for the loss in volume with a sufficient price premium for small packages.

Now, consider the case when some consumers are choosing to abstain from consumption when the firm only offers a large package size. This is the case represented in Figure 2. The introduction of small packages leads to a purchase pattern depicted in Figure 4. We

see that small packages can lead to some consumers switching to  $L_1 + S_1$  from the earlier consumption of  $2L_1$ . These consumers are in the region  $[\theta_3, \theta_1^{c0})$ , where  $\theta_3 = r/t - h/t + (p_1^s - 2p_1^l)/(\beta t)$ . On the other hand, some consumers in the region  $[\theta_1^{c0}, \theta_1^{s0})$  could buy a single small package, where  $\theta_1^{s0} = r/t - p_1^s/(\beta t)$ . Note that some consumers still continue to abstain even after the introduction of small packages. Our results show that if  $f'(\cdot) \geq 0$  in the region  $[\theta_3, \theta_1^{s0})$ , then small packages will (weakly) increase profits and total unit sales. This condition is true, for example, when  $\theta_1 < \frac{1}{2}$  or when  $f(\cdot)$  is uniform.<sup>17</sup> The intuition is that the loss in sales as a result of some consumers buying less can be compensated by the gain in new consumers who buy a small package. It is important to note that when the market is not fully covered, we do not need the condition that  $\beta < \frac{1}{2}$  for small packages to be profitable. In general, as is intuitive, with partially covered markets, small packages will be attractive for a wider range of parameters. This is because when markets are partially covered, the firm's profits can improve with small packages because of increased price premium and potentially higher unit sales.

#### 5. Duopoly Analysis

Now, we will analyze the firm's pricing and packaging decisions, given the decisions of consumers in periods 1–3. The sequence of decision is as follows. First, both firms decide on the packaging decision. In other words, they decide whether they want to offer small packages in addition to large packages. Second, after observing each others' packaging decisions, each firm decides on the specific price that it wants to charge. Finally, consumers make their purchasing decisions based on package sizes, prices, and their own preferences. Our analysis of the monopoly case shows that in some cases, all consumers could buy large packages, whereas in other situations, some consumers could choose not to purchase the product at all.<sup>18</sup> In the first case, all consumers participate in the market, and in the latter case, the market is not fully covered. In this section, we consider the case when the market is fully covered. We do this for two reasons. First, this represents a situation where the market is saturated, which is true for many vice goods. Second, this allows us to examine situations in which

<sup>17</sup> If  $\theta_1 < \frac{1}{2}$ , then log-concavity of  $f(\cdot)$  and symmetry of around  $\frac{1}{2}$  ensures that  $f'(\cdot) \geq 0$  in the relevant region.

<sup>18</sup> An alternate theoretical possibility is that consumers switch brands to practice self-control. In other words, there is preference reversal between the purchasing and the consumption stages. Although theoretically plausible, such preference reversals are not commonly observed. We therefore focus on these two cases (i.e., overconsumption and renunciation) and impose parametric restrictions to rule out self-control-induced preference reversals.

<sup>16</sup> The proofs are in the electronic companion.

the firm will necessarily lose sales when it introduces small packages. We can then examine whether even in such circumstances a firm will introduce small packages. In §6.2, we consider the case when the market could potentially expand as a result of the introduction of small packages.

In our analysis, it will be useful to distinguish between two cases:  $\theta_1 < \frac{1}{2}$  and  $\theta_1 \geq \frac{1}{2}$ . Figure 5 shows the purchase pattern for the case when  $\theta_1 < \frac{1}{2}$  and both firms offer only large packages. In this case, we see that some consumers overconsume, whereas others consume in moderation. It is important to note that this condition is more likely to be satisfied for low-valuation products when the products are highly differentiated. Figure 6 shows the corresponding purchase pattern when  $\theta_1 \geq \frac{1}{2}$ . Note that in this case, all consumers overconsume. Intuition would suggest that small packages would be more valuable to consumers in the latter case, and therefore in a competitive setting, firms would have higher incentives to offer small packages in a situation represented by Figure 6.

### 5.1. Case 1: $\theta_1 < \frac{1}{2}$

We will first consider the case when both firms offer large packages. Next, we will consider the case when both firms offer small packages along with large packages. We will then analyze equilibrium packaging decisions by both firms.

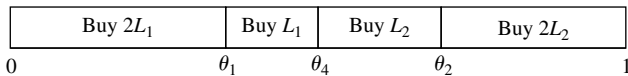
**5.1.1. Firms Offer Large Packages Only.** If both firms offer only large packages at a per-unit price of  $p_i^l$ , then the consumer who is indifferent between purchasing products 1 and 2 is indexed by  $\theta_4$ . We have

$$\theta_4 = \frac{1}{2} + \frac{p_2^l - p_1^l}{2t\beta}. \quad (11)$$

As discussed in §3.2, consumers with  $\theta < \theta_1$  will purchase two large packages. From the discussion in §3.2, we know that consumers with  $\theta \in [\theta_1, \theta_{1b})$  also consume two large packages. However, consumers in the region  $(\theta_{1b}, \theta_4)$  purchase one large package from firm 1. This is represented in Figure 5. Therefore, the profit function is given by

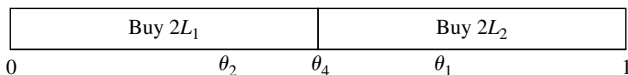
$$\begin{aligned} \Pi_1^l &= 4p_1^l F(\theta_{1b}) + 2p_1^l [F(\theta_4) - F(\theta_{1b})] \\ &= 2p_1^l [F(\theta_4) + F(\theta_{1b})], \end{aligned} \quad (12)$$

**Figure 5** Duopoly with  $\theta_1 < \frac{1}{2}$  and Market Is Fully Covered



Note. Large packages only.

**Figure 6** Duopoly with  $\theta_1 \geq \frac{1}{2}$  and Market Is Fully Covered



Note. Large packages only.

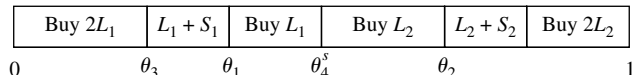
where the per-unit marginal cost is assumed to be zero. The first term in (12) represents profits from the segment that buys two large packages of product 1, and the other term represents the profits from the segment that buys a single large package.

**5.1.2. Firms Offer Both Large and Small Packages.** Now consider the case when both firms also start offering small packages, which consist of a single unit of the good. Because we are considering situations in which firms already have large packages, we will examine situations in which firms have an option to augment their product line and also offer small packages. Of course, in the long run, firms could also decide whether to only offer small packages by withdrawing large packages. In §6.3 we consider this possibility and show that, in equilibrium, firms will prefer to continue offering large packages.

Note that if  $\beta = 1$ , then in our framework, small packages will have no effect on profits. Thus, if we find that small packages are profitable, then these results are driven by consumers' self-control problems. When  $\beta < 1$ , small packages could be attractive to consumers because small packages can help consumers with their self-control problems. This is because these consumers could now get the opportunity to purchase small packages and consume less. This is essentially the idea of rationing purchases (Werthenbroch 1998). However, it is not immediately clear that the firm could benefit, because the overall unit sales would decline as long as small packages have a positive market share.

First, let us see who will buy the small packages. As discussed in §3.2, small packages only affect the decision of consumers with  $\theta < \theta_1$ . The resulting purchase pattern is shown in Figure 7. If  $\theta_1 < \frac{1}{2}$ , then consumers in the middle, i.e.,  $(\theta_1, \theta_2)$ , have the ability to consume in moderation and would therefore buy a large package. The consumers who have very strong preference for either of the products still buy two large packages and overconsume. The consumers in the range  $(\theta_3, \theta_1)$  buy one small and one large package. These consumers would consume a large package in period 1 and a small package in period 2. Thus, the introduction of small packages does reduce overconsumption for these consumers, although it does not completely eradicate overconsumption. It is important to note that in our framework, the customer segment that is attracted to small packages is endogenously determined. Interestingly, consumers with moderately high

**Figure 7** Duopoly with  $\theta_1 < \frac{1}{2}$  and Market Is Fully Covered



Note. Large and small packages.

preference for the products are the ones who purchase small packages. Consumers with very high valuations still prefer to overconsume, whereas consumers with relatively lower valuations have no overconsumption problem and buy a single unit of large package.

When both firms introduce small packages, and small packages have positive market share, then the profits for firm 1 are given by

$$\begin{aligned} \Pi_1^s = \max_{p_1^s, p_1^l(s)} & 4p_1^l(s)F(\theta_3) + (2p_1^l(s) + p_1^s)[F(\theta_1) - F(\theta_3)] \\ & + 2p_1^l[F(\theta_4) - F(\theta_1)], \end{aligned} \quad (13)$$

where we denote the per-unit price charged by firm 1 for the large package in this case by  $p_1^l(s)$  and the price of the small package by  $p_1^s$ . The first term in (13) represents the profits from the segment purchasing two large packages. The second term represents the profits from the segment buying a large package and a small package. The third term represents the profits from the segment buying only a single large package. Note that in equilibrium, we must have that  $p_1^{l*} \leq p_1^{s*}$ ; else, consumers can buy multiple units of small packages rather than a large package.

**PROPOSITION 1.** *If  $\beta < \frac{1}{2}$ , then in any symmetric equilibrium, both firms make higher profits by introducing small package sizes. Firms charge a price premium for small package sizes, but the total unit sales decline with the introduction of small packages. Furthermore, it is an equilibrium for both firms to introduce small packages if  $\beta < \frac{1}{2}$ .*<sup>19</sup>

The first part of Proposition 1 shows that when  $\theta_1 < \frac{1}{2}$ , the introduction of small packages can increase profits for both firms.<sup>20</sup> Let us first understand the reason why small packages help the firm when  $\theta_1 < \frac{1}{2}$ . Note that the consumers in  $(\theta_1, \theta_2)$  do not overconsume and continue to purchase the large packages. However, consumers at the edges of the market do have the problem of overconsumption, and small packages offer them a way by which they can reduce consumption. These consumers have high valuation for the product, which is tempered by their tendency to overconsume. However, because these consumers have relatively high valuation, the firm can offer them small packages at a high price. Note that in this case, consumers with an overconsumption problem pay a premium to the firms to help them consume less.

It is profitable for the firms to offer small packages only if the prices that they are able to charge for the small packages compensate for the lost volume. For

large values of  $\beta$ , the number of consumers who overconsume is small, and it is more advantageous for the firm to sell only the large packages. However, if  $\beta < \frac{1}{2}$ , then the firm can charge a unit price that is so high that the loss in unit sales can be made up by an increase in the prices.<sup>21</sup> Therefore, small packages enable the firms to better price discriminate among the high- and low-valuation consumers. This result is consistent with the unusually high price premiums for 100-calorie products. For example, a study by the Center for Science in the Public Interest finds that the price premiums for such products can be as high as 279%, with an average premium of 142%.<sup>22</sup>

The next proposition examines the implications of  $h$ , which represents the vice nature of the good, on small package pricing and sales. A related question is how  $h$  affects the relative profitability of introducing small packages. Note that so far, we assume that there are no fixed costs of introducing small packages. If firms incur fixed costs for introducing small packages, then small packages are more likely to be introduced as the relative profitability increases.

**PROPOSITION 2.** *If  $\beta < \frac{1}{2}$  and  $f(\cdot)$  is uniform, then firms' price premium and sales of small packages increase as  $h$  increases. Furthermore, incremental profits from introducing small packages increase as  $h$  increases.*

Proposition 2 shows that the firms can charge a higher price premium for the small package as  $h$  increases. This is intuitive because as  $h$  increases, the value of the small package for the consumers who have overconsumption problems also increases. The result, however, shows that the firm is not only able to increase prices but also sell more small packages as  $h$  increases. This implies that the total unit sales of the vice good decrease as  $h$  increases and the firm's profit increases. The last part shows that as long as the market is fully covered and  $\theta_1 < \frac{1}{2}$ , then an increase in  $h$  can actually boost firm profits. In other words, if both firms could innovate and reduce the harmful effects of their products, then such investments can reduce their profits. The reason is that the presence of  $h$  provides the firms with the ability to price discriminate

<sup>21</sup> Note that the result requires that the per-unit margins from the small package are at least twice as large as the per-unit margins from the large package. In this paper, we have assumed for simplicity that the marginal costs are zero, and therefore the prices are the same as margins. In a more general case, it can be shown that for small packages to be profitable, we require that

$$p_1^{s*} \geq 2p_1^{l*} + \beta t \left[ \frac{F(\theta_1) - F(\theta_3^*)}{f(\theta_3^*)} \right] - c.$$

For large enough  $c$ , therefore we will have  $p_1^{s*} < 2p_1^{l*}$ , but the firm's profit will still be higher by introducing small packages.

<sup>22</sup> See <http://www.cspinet.org/new/pdf/100cal.pdf> (accessed June 14, 2011).

<sup>19</sup> Although the proof is developed for the case when firms first decide package sizes and then make pricing decisions, the result would also hold if firms were to simultaneously decide on packaging and pricing. See the electronic companion for details.

<sup>20</sup> The proofs of all propositions are in the electronic companion.

by offering small packages to consumers with overconsumption problems and low price sensitivity. Now let us examine how a consumer's self-control problem as a result of the hyperbolic discounting parameter affects prices, sales, and relative profitability.

**PROPOSITION 3.** *If  $\beta < \frac{1}{2}$  and  $f(\cdot)$  is uniform, then the firm's total sales of small packages decrease with  $\beta$ . However, the price premium and incremental profits have an inverted U relationship with  $\beta$ .*

The first part of Proposition 3 shows that an increase in  $\beta$  decreases the sales of small packages. This is intuitive because an increase in  $\beta$  represents a decrease in self-control problems and a corresponding decline in the number of people who have overconsumption problems. The impact on the price premium that the firm can charge is more nuanced. First, note that an increase in  $\beta$  increases the weight that the consumer in the first period places on the harm from overconsumption. This increases the price premium that the firm can charge from small packages. On the other hand, an increase in  $\beta$  also increases the value of consumption. Because small packages lead to lower total consumption, this aspect hurts the degree of price premium that the firm can charge. For low values of  $\beta$ , when overconsumption is an issue for the larger proportion of people, an increase in  $\beta$  increases the price premium that the firm can charge. However, when  $\beta$  is larger, the second effect dominates, and the firm's price premium for small packages decreases as  $\beta$  increases. Because an increase in  $\beta$  leads to a decline in sales of small packages, incremental profits also follow an inverted U relationship with  $\beta$ .

The result in Proposition 1 suggests that the introduction of small packages enables the firm to better price discriminate. This might imply that consumers would be worse off by the introduction of small packages. We now analyze how consumer welfare is affected by the introduction of small packages. We first need to clearly specify how to measure consumer welfare. Recall that consumer's preferences change in each period because of his or her self-control problem. O'Donoghue and Rabin (2003) argue that consumer welfare in models with hyperbolic discounting should be measured using the preference of a consumer with a long-range perspective, i.e., with  $\beta = 1$ . Another way this can be justified is by asking the discount factor one would use to advise consumers (Harris and Laibson 2002). This approach of measuring consumer welfare when consumers have time-inconsistent preferences has been used by numerous other authors (see, for example, Gruber and Köszegi 2001, DellaVigna and Malmendier 2004). We therefore use this criterion to determine consumer and social welfare. Alternatively, we could also use consumer welfare from the perspective of the consumer who

makes the decision at the purchasing stage. We obtain similar results in both cases. Proposition 4 examines how small packages affect consumer welfare and social surplus.

**PROPOSITION 4.** *All consumers are weakly better off with the introduction of small packages. Furthermore, social surplus improves with the introduction of small packages.*

Intuition would suggest that the ability of the firms to better price discriminate would hurt consumer welfare. However, this is not true, and *all* consumers are weakly better off with the introduction of small packages. To understand this, first note that when small packages are introduced, the prices of the large packages remain unchanged. This is because when the firm offers both package sizes, the large package continues to compete with the other firm's large package, whereas the small package enables the firm to extract more from its own customers (see Figure 7). An increase in prices of the large package adversely affects market share. However, an increase in  $p_1^s$  only affects the size of the segment from which the firm is able to extract extra revenues. The firm therefore does not distort  $p_1^l$  and uses  $p_1^s$  to achieve its price discrimination goals. Thus, consumers could either pay the same price for the large package and overconsume or pay a higher price and buy the small package. Some consumers find it beneficial to switch to small packages, and they must receive a higher utility from this switch. Thus, consumer surplus and thereby social welfare improves with the introduction of small packages. Together, with the result in Proposition 1, this suggests that when  $\theta_1 < \frac{1}{2}$ , the introduction of small packages benefits all parties: the firms, the consumers, and society. Recalling that  $\theta_1$  increases in  $\beta$ , and  $t$  and decreases in  $r$ , our results suggest that small packages would be attractive for low-valuation goods when products are highly differentiated.

## 5.2. Case 2: $\theta_1 > \frac{1}{2}$

Now consider the case when  $\theta_1 > \frac{1}{2}$ . In this situation, absent small packages, all consumers buy two large packages of either product 1 or product 2 (see Figure 6). In this case, even consumers in the middle of the Hotelling line could be attracted to the small packages. With the introduction of small packages, the purchasing pattern is shown in Figure 8. Thus, consumers in  $(0, \theta_3^s)$  buy two large packages from firm 1 and overconsume, whereas consumers in the region  $(\theta_3^s, \theta_4^s)$  will buy one large and one small package. The profits in this case are given by

$$\Pi_1^s = 4F(\theta_3^s)p_1^l(s) + (2p_1^l(s) + p_1^s)[F(\theta_4^s) - F(\theta_3^s)], \quad (14)$$

where the first term is the profit from the segment purchasing two large packages, and the second term

**Figure 8** Duopoly with  $\theta_1 \geq \frac{1}{2}$  and Market Is Fully Covered

Buy $2L_1$	Buy $L_1 + S_1$	Buy $L_2 + S_2$	Buy $2L_2$
0	$\theta_3^s$	$\theta_4^s$	1

Note. Large and small packages.

represents the profits from consumers buying  $L_1 + S_1$ . We have the following result.

**PROPOSITION 5.** *If  $\theta_1 > \frac{1}{2}$ , then*

(a) *If both firms offer small packages, then their profits are lower than the case when both firms offer only large packages.*

(b) *If  $f(\cdot)$  is uniform and  $r \geq h$ , then in equilibrium, both firms offer only large packages.*

Proposition 5 shows that if both firms offer small packages, then they are worse off compared with the case when both offer only large packages. This is in complete contrast to the result we obtained in the case when  $\theta_1 < \frac{1}{2}$ . To understand this, note that when  $\theta_1 > \frac{1}{2}$ , the marginal consumer who is choosing product 1 over product 2 is purchasing a small package (see Figure 8). Furthermore, the marginal consumers are those who have relatively lower valuation for the product. These two aspects curtail the ability of firms to charge the self-control premium for small packages. The firm is not able to charge a sufficient premium on small packages to make up for the loss in unit sales. Furthermore, the prices of the large package decline with the introduction of small packages. Therefore, the profits of the firms go down with the introduction of small packages.

It is important to see that even in this case, the firms charge a price premium for the small packages, as they did in the case when  $\theta_1 < \frac{1}{2}$ . The reason for the disparity in prices between small and large packages, however, is very different in both of the cases. When  $\theta_1 > \frac{1}{2}$ , the consumers in the middle of the Hotelling line are consuming small packages (see Figure 8). Thus, the small packages of each firm directly compete with each other, which limits the ability of the firms to charge sufficient premium from small packages to compensate for the loss in volume. The firms therefore reduce the prices of large packages in order to induce consumers in the region  $(0, \theta_3)$  to buy two large packages rather than a single large package and a small package. Note that in contrast to this pricing approach, when  $\theta_1 < \frac{1}{2}$ , prices of large packages do not change with the introduction of small packages.

Because firms' profits decline when they both introduce small packages, ideally, they would like to be able to avoid such a scenario. Interestingly, the results suggest that if  $f(\cdot)$  is uniform and  $r > h$ , then both firms can coordinate to avoid introducing small packages and preserve their margins and sales. In particular, the incentives are not high enough for either firm

to deviate and offer small packages. Consequently, both firms continue to offer only large package sizes. It is also interesting to note that this happens precisely when the problems of overconsumption are more prevalent in the market.<sup>23</sup>

Finally, it is easy to see that consumer welfare would be higher if firms were to introduce small packages. Thus, unlike the case when  $\theta_1 < \frac{1}{2}$ , the incentives of the firms and consumers are not aligned in this situation. Comparing the results of Propositions 1 and 5 with the monopoly results, we see that for fully covered markets, the monopolist will introduce a small package as long as  $\beta < \frac{1}{2}$ , regardless of the value of  $\theta_1$ . Thus, the presence of competition reduces the parameter range over which firms offer small packages.

## 6. Model Extensions

Now we extend the base model to relax some assumptions. This allows us to examine the validity of our results in the previous section as well as to provide new insights.

### 6.1. Consumers Do Not Form Rational Expectations

In the base model, we assumed that consumers in period 1 rationally anticipate their consumption behaviors and try to correct for it when they make their purchasing decisions. However, consumers may not be able to correctly predict consumption behavior. To model this, we assume that the consumer in the purchasing stage believes that the second-stage consumer uses a hyperbolic discount factor  $\hat{\beta} \geq \beta$  (see O'Donoghue and Rabin 2001, DellaVigna and Malmendier 2004). If  $\hat{\beta} = \beta$ , then the consumer has rational expectations. If  $\hat{\beta} = 1$ , then the consumer (incorrectly) believes that he will have no self-control problem in the consumption stage. If  $\hat{\beta} > \beta$ , the consumer has false optimism about his behavior in the consumption stage. The consumer in stage 1 believes that he has an overconsumption problem only if  $\theta \leq \hat{\theta}_1$ , where

$$\hat{\theta}_1 = \frac{r}{t} - \left( \frac{\hat{\beta}}{1 - \hat{\beta}} \right) \cdot \frac{h}{t} < \theta_1. \quad (15)$$

Thus, consumers in the region  $(\hat{\theta}_1, \theta_1)$  will underestimate their overconsumption problems.

First, consider the case when  $\theta_1 < \frac{1}{2}$ . If firms offer only large packages, then consumers in the region  $(\hat{\theta}_1, \theta_1)$  will buy a single large package and end up

<sup>23</sup> The proposition is, however, proved only for the uniform distribution. It is possible that there are other distributions in which the equilibrium is for both firms or only one firm to offer small packages.

consuming it in one period. This hurts the unit sales of the firm. Because the number of consumers who purchase two large packages declines, it also affects firms' prices. In fact, the prices of both firms are lower when consumers are not fully rational (see the electronic companion for details). Interestingly, these incorrect expectations help some consumers by increasing price competition. Now, consider the case when the firm could offer small packages. The number of consumers who are interested in the small packages is lower because some consumers falsely believe that they do not have overconsumption problem. We have the following result.

**PROPOSITION 6.** *If  $\theta_1 < \frac{1}{2}$  and  $\hat{\beta} < \frac{1}{2}$ , then both firms introduce small packages. Firms' prices, profits, and sales of small packages are lower when consumers do not form correct expectations, as opposed to the case when consumers form rational expectations.*

The first part of Proposition 6 shows that when  $\theta_1 < \frac{1}{2}$  and consumers do not form correct expectations, firms are less likely to introduce small packages. Since  $\hat{\theta}_1 < \theta_1$ , this implies that small packages are less likely to be introduced when some consumers do not have overconsumption problems, i.e.,  $\theta_1 < \frac{1}{2}$ , and consumers fail to form rational expectations. The results also suggest that a firm's ability to charge a price premium is also reduced in such a case. Thus, the overall impact of incorrect expectations on consumer welfare need not be negative. In fact, some consumers are clearly better off when all consumers do not form rational expectations.

Now consider the case when  $\theta_1 > \frac{1}{2}$ . If  $\hat{\theta}_1 > \frac{1}{2}$ , the analysis remains unchanged, and consumers' incorrect expectations do not affect the market outcome. Interestingly, however, it is possible that  $\hat{\theta}_1 < \frac{1}{2} < \theta_1$ . In this case, unlike the case of rational expectations, firms may find it beneficial to offer small packages even when the market is fully covered.

**PROPOSITION 7.** *Suppose that  $\theta_1 > \frac{1}{2}$  and  $\hat{\beta} \in ((2r - t)/(2(r + h) + t), \frac{1}{2})$ ; then both firms introduce small packages.*

Proposition 7 thus shows that when consumers' expectations are such that consumers in the middle of the Hotelling line falsely believe that they will not overconsume, firms could find it beneficial to offer small packages. The impact of incorrect expectations on firms' profits is ambiguous. First, note that when consumers form incorrect expectations, the sales and prices for the case of the large package only are lower compared with the base case with rational expectations. Although the ability to introduce small packages provides firms with the ability to better price discriminate, this may still not be enough to compensate for the loss in prices and sales.

## 6.2. Market Is Not Fully Covered

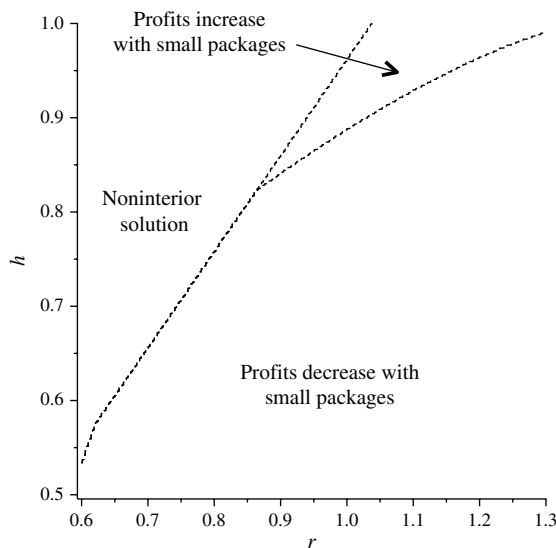
We now consider the case when some consumers decide not to purchase the product rather than overconsume. This implies that when firms only offer large packages, the market is not fully covered. We assume that  $f(\cdot)$  is uniform. First, consider the case when  $\theta_1 < \frac{1}{2}$ . The analysis in this case reinforces our earlier results.<sup>24</sup> We find that firms benefit from offering small packages, and consumers and society are better off. However, unlike the fully covered case, the condition  $\beta < \frac{1}{2}$  is not necessary. Furthermore, it is not necessary that margins for the small package be double the margins for the large package. This is because the increase in the sales of small packages compensates for the loss in volume. Therefore, the results in Proposition 1 hold for a wider range of parameters when the market is not fully covered.

Now consider the case when  $\theta_1 > \frac{1}{2}$ , and the overconsumption problem is more prevalent. In this case, the introduction of small packages is likely to bring more consumers into the market. Note that for  $\theta_1 > \frac{1}{2}$ , the consumers in the middle of the Hotelling line do not purchase the product. This implies that the firms in this case act as monopolists. Our earlier results for monopoly therefore imply that profits would increase in this case, when the firms introduce small packages. To consider a situation in which both monopoly effects and competitive effects exist, we modify the analysis. In particular, we assume that each firm caters to two equal-sized segments. One of the segments is not fully covered and only buys from firm 1 (if at all), whereas both firms compete in another segment that is fully covered. Similarly, firm 2 has a segment of consumers that only buys from it, and the other segment is fully covered and potentially buys from either firm. This formulation allows for the possibility that the market is not fully covered while still ensuring that the firms directly compete with each other.<sup>25</sup> We will make an additional assumption that  $t = 1$  and focus on interior solutions in which at least some consumers purchase two large packages. Figure 9 depicts the change in profits for the firm when both firms introduce small packages. Note that even in this case, the introduction of small packages can hurt profits. This reinforces the result in Proposition 5

<sup>24</sup> The proofs of the results presented in §6.2, 6.3, and 6.4 are available from the author upon request.

<sup>25</sup> This can also be viewed as a model with consumers distributed in the range  $(-1, 2)$  with the firms located at 0 and 1. In this case, consumers in the region  $(-1, 0)$  only buy from 1, if at all, whereas firms compete for the consumers in the region  $(0, 1)$ . An alternate formulation, with similar results, would have two segments with different consumption utility  $r_i$ . For segment 1, we could assume that  $r_1$  is sufficiently high, so that all consumers are in the market. However, in segment 2,  $r_2$  is such that the market is not fully covered.

**Figure 9**  $\theta_1 > \frac{1}{2}$  and Market Is Not Fully Covered



and shows that as long as there is significant competitive interaction between firms, then for  $\theta_1 > \frac{1}{2}$ , firms' profits can be lower with the introduction of small packages. We also find that the profits of the firm in this case decrease as  $h$  increases. Therefore, in this scenario, firms can benefit from focusing on producing healthier products that lead to lower long-term harm. This is in contrast to the case where  $\theta_1 < \frac{1}{2}$ , where an increase in  $h$  increases profits, because it improves the firms' ability to price discriminate. Finally, we find that if  $r \geq 321/418 + 207h/209$ , then the total unit sales increases if firms introduce small packages. Interestingly, consumer welfare is higher with the introduction of small packages even when the total unit sales (and consumption) of the vice good increases.

### 6.3. Firms Could Withdraw Large Packages

In the base model, we assumed that firms have the option of introducing small packages in addition to their existing product line. However, we assumed that firms do not withdraw their existing large packages. If we allow firms to withdraw large packages, then we must consider a few additional candidates for equilibrium. It is easy to show that even in a general setting, the symmetric case where both firms only offer small packages is Pareto-inferior to the equilibrium identified in Propositions 1 and 5. Therefore, if we were to focus on the symmetric Pareto-superior solution, our equilibrium results still hold. However, we would still need to show that the equilibrium identified in Propositions 1 and 5 are valid equilibria and rule out alternate asymmetric equilibria. To analyze this, we assume that the preference distribution is uniform, with a range of  $(0, 1)$ . If  $\theta_1 > \frac{1}{2}$ , then we can show that the unique equilibrium is for both firms to only offer large packages. If  $\theta < \frac{1}{2}$ , we make an additional

assumption that  $t = 1$  and find that we can rule out all the asymmetric equilibria. Therefore, the main results of this paper continue to hold even when we allow firms to withdraw large packages.

### 6.4. Asymmetric Firms

We now briefly consider the situation in which only one firm produces a vice good and competes with a firm that produces a healthy good. Specifically, assume that firm 2's products are healthy, with no long-term harm. Therefore, consumers can consume two units of product 2 in each period, but they face long-term negative consequences if they consume two units of product 1. As before, we find that if the marginal consumer who is indifferent between firms 1 and 2 does not have an overconsumption problem, then firm 1 will find it beneficial to introduce small packages as long as  $\beta < \frac{1}{2}$ . On the other hand, if the marginal consumer does have a self-control problem, then the introduction of small packages would hurt firm 1's profit. Thus, the basic nature of the results reported in Propositions 1 and 5 hold in this case.

## 7. Managerial Implications and Conclusion

In this paper, we consider a situation in which firms sell a vice good and consumers have self-control problems at the consumption stage. In particular, some consumers overconsume the product at the consumption stage. To correct for this, consumers sometimes limit their purchases or have a lower willingness to pay for the product. Firms can help consumers consume in moderation by offering small packages. However, the resulting substitution of large packages with small packages poses a risk for the firms in that it can reduce total unit sales and thereby a firm's profits. Our results provide insights into the following questions.

1. *When should firms offer small packages?* Our results show that it is profitable for firms to offer small packages when the proportion of consumers with overconsumption problems is small or when many consumers abstain from purchasing large packages because of their self-control problems. Both of these cases are more likely to happen for low-valuation, highly differentiated products. In the first case, firms can better price discriminate by selling small packages to high-valuation consumers as a means of exerting self-control. In the latter case, the introduction of small packages can increase demand.

2. *How does the degree of harm by vice good affect prices and profits?* Our results show that when only a few consumers tend to overconsume, the vice nature of the good can actually increase firms' prices and profits. This is because the vice nature of the good enables

firms to offer small packages as a means of reducing overconsumption. Thus, firms produce a vice good to consumers with self-control problems and then offer them a small package at a price premium to help them exert self-control. In this process, the firm makes more money as opposed to the case when the product was a normal good with no long-term harmful effects. Thus, our results suggest that an investment in producing healthier alternatives could sometimes hurt firms' profitability, despite the fact that consumers' willingness to pay for such products is higher. However, when most consumers have overconsumption problems, firms can benefit by reducing the harm from overconsumption of their product.

3. *What is the impact of small packages on prices?* Our results show that the introduction of small packages can sometimes lead to higher prices but at other times can decrease prices. In particular, when the market is covered and only a few consumers have overconsumption problems, then small packages lead to higher average prices. On the other hand, when the market is covered and there is a large proportion of people who tend to overconsume, the introduction of small packages will lead to more intense price competition and reduced prices.

4. *Can small packages lead to higher consumption of vice goods?* We find that when there are some consumers who abstain from buying the product and a large proportion of consumers have overconsumption problems, then small packages can lead to higher total unit sales of vice goods.

5. *What is the impact of introducing small packages on consumer and social welfare?* Our results suggest that, in general, small package introduction will lead to improved consumer and social welfare. This holds true even if consumers pay a higher price for buying small packages or when the consumption of vice goods increases with the introduction of small packages.

6. *How does competition affect firms' incentives to offer small packages?* Our results suggest that a monopolist is more likely to offer small packages. Competition decreases the range of parameters for which it is profitable for firms to offer small packages. From a public policy perspective, this suggests that in certain situations, the government may need to provide more incentives for firms to adopt small packages for vice goods.

The framework that we have presented in this paper could be used to address several other related issues. Here, we have focused on only one of the strategies that firms can use to help consumers practice self-control. However, another widely used approach is to introduce products that have lower long-term harmful effects. This is the case of introducing products with low fat, sugar, and carbohydrates. Our results in Proposition 1 suggest that it is

not always the case that introducing such products will increase profits.<sup>26</sup> Future research can consider scenarios in which firms can change both the package size and the future harm from overconsumption of the product by investing in research and development. Finally, there is need for more empirical research to examine the competitive implications of package design in the context of vice goods.

### Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at <http://mktsci.journal.informs.org/>.

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<sup>26</sup> However, there are other issues that one may need to consider when studying the development of healthy goods. First, unlike the case of changing package size, developing healthier foods require substantial R&D expenses, and the outcome of the R&D process is not certain. Furthermore, there is evidence that suggests that healthier alternatives to existing foods are often perceived as providing lower immediate benefits, such as taste (Ragunathan et al. 2006).



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