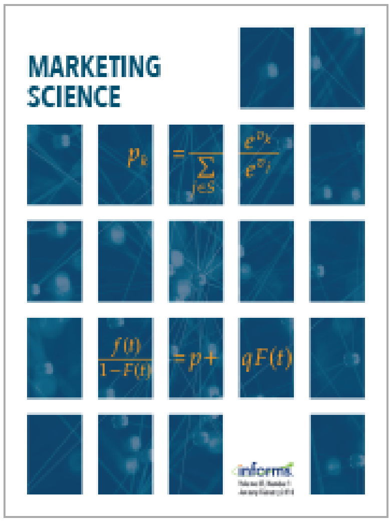

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Pricing and Product Design for Vice Goods: A Strategic Analysis

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Abstract. The rising obesity epidemic is a worldwide concern for consumers, firms, and policy makers. One reason for the rise in obesity is consumers' over-consumption of vice goods such as cookies, crackers, and soft drinks. Some authors have suggested that firms have incentives to make vice goods unhealthier and to encourage over-consumption. There are calls for regulations to ensure that firms make such products healthier by reducing harmful ingredients and provide nutritional information. Furthermore, public policy makers have begun to educate consumers to avoid over-consumption by using strategies such as pre-purchase planning. In this paper, we investigate how firms selling vice goods should respond to the growing concerns about obesity. We analyze how firms should adjust prices and product design to cater to consumers with self-control problems and obesity concerns. We use the literature on hyperbolic discounting to model consumers with self-control problems. In this framework, we examine how the unhealthiness of vice goods affects prices, firm's profits, consumer surplus, and public health. In addition, we study how public policy efforts to encourage pre-purchase planning impact firm's profits and consumers. Our results show that unlike standard goods, for vice goods a decrease in quality (i.e., increase in unhealthiness) and an increase in price can serve as a self-control device and increase demand. Therefore, firms sometimes can charge higher prices and make more profits by producing unhealthier products. Interestingly, producing unhealthier products can sometimes increase consumer surplus and improve public health. We also show that as the proportion of consumers who use pre-purchase planning increases, firms should respond by raising prices. In such situations, consumer surplus and public health improve but firm's profits decline. These results have important implications for restaurants and firms that sell vice goods and for public policy makers who aim to combat obesity.

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Keywords: vice goods • behavioral economics • hyperbolic discounting • game theory

1. Introduction

Obesity is a worldwide concern for public policy makers, consumers, and firms. According to the World Health Organization (WHO), 35% of adults in the world are considered overweight, and 11% are obese. More than 2.8 million people die each year as a result of being overweight or obese (WHO 2013). The population affected by obesity continues to grow. It is expected that by 2030, 42% of the U.S. population will be obese (Braun 2012). This could lead to an increase of \$66 billion in health care costs and a \$566 billion loss in economic productivity. A major reason for the rise in obesity is over-consumption of vice goods such as fast food, carbonated drinks, crackers, cookies, and ice cream. The rise of obesity has also been related to insufficient incentives for firms producing vice goods to improve nutrition and discourage consumers from over-consumption (Dobson and Gerstner 2010, Roberto et al. 2010). Many authors claim that firms invest significant research and development (R&D) to make products such as cookies, chips, and ice cream more addictive which in turn leads to over-consumption (see, for example, Moss 2014).

To combat obesity, public policy makers and consumer advocates have suggested various approaches. Some have suggested regulations. For example, in 2012, New York passed the Sugary Drinks Portion Cap Rule, which prohibited the sale of many sweetened drinks more than 16 ounces (Lerner 2012).[1] The Food & Drug Administration (FDA) has set a 2018 deadline for removal of artificial transfat from processed foods (Tavernise 2015). Others have suggested that firms be required to provide nutritional information at the point of purchase (FDA 2015). The efficacy of these strategies is unclear. For example, many experts disagree as to whether the introduction of e-cigarettes is necessarily good for consumers. E-cigarettes are often considered healthier than regular cigarettes since they contain less harmful substances. For example, a 2015 study by the Public Health Agent in the United Kingdom estimated that e-cigarettes are 95% safer than traditional cigarettes (McNeill et al. 2015). However, many experts are concerned that this decrease in harmful ingredients in e-cigarettes could lead to the unintended consequence of increased nicotine consumption (Bravo et al. 2016, Tobacco-Free Kids 2016). Behavioral research has also shown that relatively healthier vice goods could make the problem of over-consumption worse and make consumers worse off (see, for example, Wansink and Chandon 2006, Scott et al. 2008, Ma et al. 2013).

An alternative approach to combat the obesity epidemic is to educate consumers and help them develop strategies that could reduce over-consumption. One of the most effective techniques to avoid over-consumption is avoidance of situations in which one faces temptation (Hoch and Loewenstein 1991). For example, by planning ahead, consumers can avoid shopping in a store or dining in a restaurant if they foresee that they would be unable to control consumption and likely to overconsume. A large stream of behavioral literature shows that avoidance and precommitment strategies are effective in exerting self-control (see, for example, Rook and Hoch 1985, Myrseth and Fishbach 2009, Fujita 2011, Crockett et al. 2013). While this research has examined the consumer behavior implications of such strategies, it has not studied how firms will optimally react to these strategies and how this in turn will affect consumer welfare. Furthermore, researchers have not examined how public policy makers should design policies taking into account firm and consumer reactions to such changes. Some theoretical research has addressed package size issues in the context of vice goods. Dobson and Gerstner (2010) show how supersizing can be beneficial to firms. Jain (2012) shows how firms can improve profits by offering smaller packages. His results suggest that firms could benefit by producing unhealthier products since it enables them to better price discriminate by offering small packages as self-control devices. He also shows that competition could sometimes limit the ability of firms to price discriminate by offering small packages. In such situations, it may be better to offer healthier products. However, Jain (2012) does not consider situations in which such price discrimination by offering small packages is not possible. He also does not consider how consumer strategies of pre-purchase planning affect firm's incentives to produce unhealthy products and how unhealthiness affects firm's profits, consumer health, and consumer welfare.

The rise in obesity and increasing awareness of health-related issues raise several important questions which, to our knowledge, remain unexplored in prior literature. From a firm's perspective, it is important to understand how it should respond to consumers' growing concerns about over-consumption. Firms can adjust their prices and product design to address concerns about vice goods. In particular, firms can respond to growing health concerns by changing product design to make products less harmful. Alternatively, firms could respond by decreasing prices. Furthermore, how would public health programs that educate consumers to preplan affect firm strategies? From a public policy perspective, it is also important to understand the impact of consumer education efforts that help consumers avoid over-consumption on firm profits, consumer welfare, and the long-term consumer health. Our goal here is to formally examine firm's pricing and product design strategies for vice goods when consumers have self-control problems. We study how growing consumer awareness of obesity issues and use of preplanning affects firm's strategies. In addition, we study the impact of firm strategies on consumer health and welfare. This analysis can inform managers on how to design and price vice goods and public policy makers on how to combat the growing obesity crisis.

To address these questions, we develop a game-theoretic model in which consumers make decisions about purchase of vice goods. We model vice goods by assuming that moderate consumption of these goods is not harmful while over-consumption leads to a long-term harm on consumer's health. Unlike standard goods, a unique feature of most vice goods is that consumers are often unable to control consumption, even though they later realize that they should not have overconsumed (Kivetz and Keinan 2006, Wertenbroch 1998, Hoch and Loewenstein 1991). To model the fact that consumers of vice goods struggle with self-control, we use the literature on hyperbolic discounting. This literature has been widely used to model self-control problems that individuals face in a variety of different contexts (see, for example, Laibson 1997, DellaVigna and Malmendier 2004, Gilpatric 2009, Jain 2012).

We first study the case wherein consumers make their purchase decision at the store and do not preplan. Our results suggest that in such situations, unhealthier products could lead to *less* over-consumption and improved health. This is consistent with empirical findings that consumers are more likely to consume relatively healthy goods (e.g., Wansink and Chandon 2006, Scott et al. 2008, Ma et al. 2013). These authors have attributed such increased consumption to consumers' incorrect inferences about caloric content, decreasing guilt or other decision errors. Furthermore, the authors do not consider optimal firm response to changes in nutrition. In our framework, over-consumption of relatively healthier vice goods can happen even when consumers correctly estimate the harm from over-consumption and is the result of a trade-off between future harm and more immediate gratification. Furthermore, the results hold even when we account for optimal firm response. This result therefore cautions public policy makers from mandating that firms produce relatively healthier products as this could lead to higher levels of over-consumption. We find that when consumers do not preplan, firms will have incentives to reduce the unhealthiness of their products and that such incentives could be higher with competition. Our results show that consumer preplanning can substantially change the results. In particular, we find that when many consumers preplan, unhealthiness can act as a self-control device that can lead to increased demand by planners. Also, we find that higher prices by firms can also serve as a self-control device that could discourage planners from abstaining. For this reason, decreased quality (i.e., increased unhealthiness) and higher prices of vice goods can increase demand and profits. This is very different from the case of standard goods where decreased quality or increased prices would always decrease demand. Our results suggest that when consumers preplan, a monopolist will have less incentives to invest in producing healthier goods. In other words, a focus on educating consumers to preplan their purchases could discourage a monopolist from investing in healthier products and therefore hurt consumers who do not preplan. Interestingly, we find that in the presence of large numbers of planners, there is an asymmetric equilibrium in which ex ante symmetric firms choose different strategies. In particular, one firm produces a less unhealthy product while the other firm produces a more unhealthy product. In this situation, we find that reduction in unhealthiness of a vice good can serve as a coordination device to reduce price competition. Our paper adds to the growing literature in marketing and economics that has modeled self-control problems using hyperbolic discounting (for example, Laibson 1997, DellaVigna and Malmendier 2004, Gilpatric 2009, Dobson and Gerstner 2010). Our paper is more broadly related to the growing literature in marketing that seeks to enrich standard economic models by incorporating psychological and sociological realism (see, for example, Carpenter and Nakamoto 1990, Wernerfelt 1995, Amaldoss and Jain 2005, Syam et al. 2008, Villas-Boas 2009).

The remainder of the paper is organized as follows. In Section 2, we develop our model and consider the case when consumers do not pre-plan. In Section 3 we consider the case when some consumers use the strategy of preplanning their purchases. We discuss our results and the implications of relaxing some assumptions in our model in Section 4. In Section 5, we conclude with a discussion of managerial and public policy implications, and directions for future research.

2. Model

We first consider the case when there is a monopolist selling vice goods to consumers who have self-control problems. Later we will study competition. This sequential analysis helps us better delineate the role of consumers' self-control problems and of competition in the case of vice goods. The marginal cost for producing each unit of the product is $c > 0$. We assume that the monopolist is at point 0 on a Hotelling line of unit length. The consumer at θ on the Hotelling line gets an immediate benefit of $\bar{v} - \theta - p$ from consuming the vice good where p is the price of the good. Consumers are heterogeneous and θ is distributed on a Hotelling line with continuous distribution function $f(\cdot)$ with range $(0, 1)$. We assume that the cumulative distribution function $F(\cdot)$ is concave. The assumption is satisfied by several distributions including the uniform distribution, left triangular distribution, and various families of the beta distribution. We also assume that $\bar{v} > c$ so that the firm will want to serve some consumers.

To model vice goods, we follow the approach used by Jain (2012). Vice goods have two important characteristics. First, moderate consumption of such goods is not harmful while over-consumption leads to significant harm. This could be physiological or psychological, such as feelings of guilt. For example, cookies, chocolate, and alcohol are not harmful when consumed in moderation (see, for example, Baum-Baicker 1985, Stampfer et al. 1988, Jenkins et al. 1995, Barba et al. 2006). However, when consumed in large quantities, these products can lead to long-term adverse health effects (e.g., Li and Heber 2012). Stated in model terms, the total harm that the consumer incurs is a convex function of the units consumed. To model this simply, we assume that a person can consume at most two units of the product: While consuming one unit has no negative consequences, consuming two units is considered over-consumption and leads to delayed negative harm of h.[2] The parameter $h \in [\underline{h}, \bar{h}]$ reflects the unhealthiness of the vice goods. If h is small, the long-term harm is small and the product is less unhealthy. To capture the vice nature of the product, we assume $\underline{h} > 0$. If h is larger, the long-term harm is more severe and the product is unhealthier. Consumers are concerned about over-consumption and make decisions by taking the future harm of over-consumption into account. Note that we assume that all consumers experience the same h. It is possible that consumers may experience different levels of harm or place different weights on the level of harm. In Section 4.1 we consider a model that allows this and find that the main results continue to hold.

Another important characteristic of vice goods is that consumers are often unable to avoid over-consumption, although they ex post regret such an action. This inability to ration consumption is often blamed for the rising obesity epidemic (e.g., Fishbach and Dhar 2005, Fishbach and Zhang 2008, Wertenbroch 1998). To model this self-control problem, 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, Carillo and Mariotti 2000, DellaVigna and Malmendier 2004, Machado and Sinha 2007, Gilpatric 2009, Jain 2012).[3] In particular, the discount function is given by

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

where β is the quasihyperbolic 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. Furthermore, the formulation assumes that the exponential discounting factor is 1. This assumption is also commonly used in prior literature on self-control (see, for example, O'Donoghue and Rabin 1999, Gilpatric 2009).

The timing of the game is as follows. At the beginning, the firm decides on product design in terms of the level of unhealthiness, and then decides on price. This sequential decision of product design and pricing is appropriate since design decisions are less flexible while prices are easier to change, although this distinction is only important for the case of competition. After observing the firm's product and pricing decisions, consumers make a sequence of decisions. From the consumer's perspective, there are three time periods, i.e., periods 0, 1, and 2. Period 0 is the pre-purchase planning stage discussed in Section 3. In period 0, a planner decides whether to shop for the product by considering the consequence of shopping. In period 1, the planner who decides to shop arrives at the store and decides how many units of the product to buy. Impulsive consumers differ from planners in that they skip the planning stage and arrive at the store to make purchase decisions directly. If a consumer buys two units of the product, i.e., if there is over-consumption, the consumer incurs a long-term harm in period 2. We will solve the game using backward induction. Specifically, we analyze consumers' decisions and solve for the pricing stage of the game to examine the impact of h on equilibrium outcomes. These results apply in situations when h has been exogenously determined and firms cannot change h in the short term. Then, we analyze firms' endogenous choice of h when firms could adjust h.

Note that the quasihyperbolic discounting captures consumer's self-control problems in a simple way. In period 1, a consumer discounts consumption utility by a factor of 1 and the long-term harm by a factor of β. However, the same consumer would discount consumption utility and long-term harm equally in period 0. Thus, while the consumer in period 0 (or period 2) may prefer not to overconsume, the consumer in period 1 may do so. This time inconsistency captures the fact that consumers are often unable to control consumption and also that the same consumer might ex post regret their consumption. In the next section, we analyze the case when consumers do not preplan their purchase. In Section 3, we analyze the case when consumers pre-plan their purchase.

At this point, it is useful to clarify the scope of our paper. We focus on vice goods with two characteristics. First, over-consumption of vice goods is harmful. Second, consumers would ex ante prefer not to overconsume although self-control problems may lead them to overconsume. For example, while baked potato chips are healthier than regular fried chips, most consumers would consider over-consumption of these to be undesirable. By contrast, consumers may not find consuming several servings of fruits and vegetables to be harmful, although over-consumption of these goods could also lead to long-term harm. Most of our results in this section (except the results on consumer welfare) would hold even if we dispense with the assumption that consumers would not rationally overconsume. However, our main results in Section 3 would require that consumers do not rationally overconsume. If this were not true, then preplanning would not be useful and our results in Section 3 do not apply.

2.1. Monopoly

We first analyze the consumer decision. The consumer finds it beneficial to purchase at least one unit if $\theta \le \bar{v} - p \equiv \theta_1$. Purchasing two units of the product is preferred to one unit if $2(\bar{v} - \theta) - 2p - \beta h > \bar{v} - \theta - p$. Thus, consumers with $\theta \le \bar{v} - p - \beta h \equiv \theta_2$ overconsume. Over-consumption will result in a harm h in period 2. Consumers whose $\theta \in (\theta_2, \theta_1]$ purchase only one unit. Consumers whose $\theta > \theta_1$ do not purchase the product. Note also that in our framework, consumers always have a healthy option available to them. In particular, consumers can always choose to buy one unit and not incur any long-term harm. Because our focus is vice goods, we assume that no consumer would a priori prefer to overconsume, i.e., $2\bar{v} - 2p - h < \bar{v} - p$. This implies that we need $\bar{v} < h + p$. A sufficient condition to ensure this is that $\bar{v} < h + c$. This assumption, while consistent with the notion of vice goods, is not critical and is used mostly for welfare analysis.

When h has been exogenously determined, the profit function for the firm is given by

$$\Pi = \begin{cases} [F(\theta_1) + F(\theta_2)](p - c) & \text{if } p < \bar{v} - \beta h, \\ F(\theta_1)(p - c) & \text{otherwise}, \end{cases} \tag{2}$$

where the first term represents the case when some consumers overconsume, while the second case is for the situation in which no one overconsumes. If $p < \bar{v} - \beta h$ then the first-order condition for price is given by

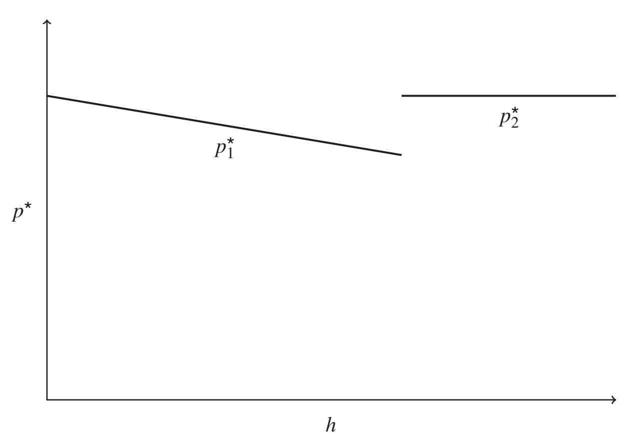
$$-(f(\theta_1) + f(\theta_2))(p^* - c) + F(\theta_1) + F(\theta_2) = 0. \quad (3)$$

Note that since prices are bounded between $(c, \bar{v})$, optimal price exists. Also, the concavity of $F(\cdot)$ ensures that the profit function is concave and therefore that there is a unique optimal price. We have the following result.

Proposition 1. *As products become unhealthier*:
(a) *Firm's profits weakly decrease.*
(b) *Prices decrease and then increase.*
(c) *If $f'' \leq 0$ then total sales decrease.*

Proofs are provided in the appendix. The first part of the proposition shows that the firm makes lower profits for unhealthier goods. If one views an increase in h as a decrease in quality, then the results are consistent with intuition. We find that prices decrease and then increase in h. To understand this result, first note that the firm's pricing strategy determines whether consumers overconsume. In particular, if the prices are low then some consumers will be tempted to overconsume. On the other hand, if prices are high then consumers will not overconsume. When h is low, the firm finds it profitable to decrease its prices to incentivize the high-valuation consumers to buy two units. Note that to encourage more buying by high-valuation consumers, the firm ultimately provides a discount to the marginal consumers. However, for large enough h, the firm prefers to forego its attempts to induce overconsumption and charges a high price such that no consumers overconsume, thus leading to a price jump (see Figure 1). Finally, note that the unit sales decline as h increases, despite the fact that prices could decline with h. This is because the direct negative effect on

Figure 1. Prices Change with h: Impulsive Consumers Only



Note. The parameters used for the figure are: $\bar{v} = 2$, $\beta = 0.5$, and $c = 0.4$, and θ is uniformly distributed.

sales from an increase in h is higher than the indirect positive effect via changes in prices.

Now, consider the firm's decision on h. In particular, the firm can choose the level of product unhealthiness by modifying the product design. For example, firms could use healthier nutrients or develop new technologies to reduce the harm that consumers incur by overconsumption of vice goods. We assume that firms incur a fixed cost to produce a product with harm h.[4] In particular, we assume that it costs $\mathscr{C}(h)$ to make a product with harm h. We also assume that this function is convex in h with $\mathscr{C}'(\underline{h}) < 0$. Thus, the cost function is U-shaped with a cost minimizing h that we denote by h_e, where $\mathscr{C}'(h_e) = 0$. Thus, h_e is the cost minimizing level of h. We assume that h_e is in the feasible range $(\underline{h}, \bar{h}]$. Note that this cost function allows for the possibility that cost is decreasing throughout as h increases. This happens when $h_e = \bar{h}$. Absent any demand consideration, the firm would choose $h = h_e$. However, deviating from h_e would require investing in additional fixed costs. This assumption is plausible in situations when firms invest in production infrastructure or R&D to replace harmful ingredients with healthier alternatives (UNSCN 2016). For example, to produce organic foods, suppliers need to invest in environmental enhancement and protection to avoid pollution (FAO 2017). Let the feasible range of h be $[\underline{h}, \bar{h}]$. When some consumers overconsume the product, we have the following result.

Proposition 2. *The monopolist chooses $h^* < h_e$.*

This result shows that the monopolist will have incentives to invest in making products less unhealthy than it would absent demand considerations. The reason is as follows: When some consumers overconsume the product (i.e., $\theta_2 > 0$), producing less unhealthy products can lead more consumers to overconsume the product (i.e., θ_2 increases). As a result, volume sales increase and firm's profits are higher. When the marginal consumer at θ_2 is indifferent between overconsuming and not buying the product (i.e., $\theta_2 = 0$ and $p^* = \bar{v} - \beta h$), producing less unhealthy products increases prices without changing volume sales. Consequently, the firm's profits increase. When no consumers overconsume the product (i.e., $\theta_2 < 0$), firm's profits do not change with h. Therefore, demand-side factors (weakly) lead the firm to produce less unhealthy products than what would minimize costs (i.e., h_e).

This result is in contrast to the claim that firms may prefer to make products unhealthier. This is also consistent with observations that many firms are introducing healthier versions of their products. For example, Kraft claims that it has introduced 5,000 healthier products since 2005. Coca-Cola has reduced its average number of calories in drinks by 9% since 2000

(The Economist 2012). Indeed, low-calorie and low-fat products are commonly recommended to the public for weight control (NIH 2016, ACS 2015).

Intuition would suggest that firms' investment in less unhealthy products will improve consumer health and surplus. Many consumer organizations have called for stricter regulation so that firms make products less unhealthy (Martin 2010). Next, we examine the public policy implications of changes in the unhealthiness of products to see whether our intuition always holds. The usual approach is to examine implications of a policy change on consumer surplus (CS). However, in the current context, it is also important to examine the impact on public health or the long-term health of consumers. Note that the CS measure considers three different aspects, i.e., instantaneous consumption utility, the price that the consumer pays for the product, and the long-term harm that the consumer incurs by the consumption of vice goods. Thus, CS could increase even if the long-term harm from consumption of a vice good increases. From a public policy perspective, such an outcome may not be desirable, since it is plausible that the long-term harm is of more interest to policy makers. Especially for the purpose of reducing obesity, overall consumer health is a pressing and more relevant objective for public policy makers. Indeed, most of the policy discussions about the consumption of vice goods are framed in terms of the consequences of such consumptions on obesity and the resulting social harm (see, for example, Arsenault 2010, Kuo et al. 2009, Variyam 2008). Therefore, we will study both these measures, focusing more on overall consumer health.

We define public health by quantifying the long-term harm that all consumers suffer due to over-consumption. A lower value of the total harm corresponds to better consumer health. On the surface, it seems intuitive that producing less unhealthy products reduces consumers' intake of unhealthy goods and would improve consumer health. Conversely, producing unhealthier products leads to public health issues such as obesity. This is the premise for policy makers to urge firms to reduce harmful ingredients such as trans fat and sugar in their products.

An alternative measure to determine whether consumers are better off is CS. In fact, this is the more commonly used criterion. Before using it, however, we need to examine how we can determine consumer welfare since the consumer's utility varies across time periods due to hyperbolic discounting. O'Donoghue and Rabin (2003) argue that in such models consumer welfare should be measured using the preference of a consumer with a long-range perspective, i.e., with $\beta = 1$ (see also Harris and Laibson 2002). Because this approach to measuring consumer welfare when consumers have time-inconsistent preferences has been used by numerous other authors (see, for example, Gruber and Kőszegi 2001, DellaVigna and Malmendier 2004), we will use it here to determine consumer welfare.

Proposition 3. *As products become unhealthier*:

(a) *Fewer consumers overconsume.*

(b) *For large h, overall consumer health weakly improves*; CS *improves when consumers overconsume.*[5]

The first part of the proposition shows that unhealthier goods reduce over-consumption. In other words, making products less unhealthy could make the problem of over-consumption worse. Such over-consumption of relatively healthy vice goods has been observed in prior empirical research (e.g., Wansink and Chandon 2006). These authors have attributed such increased consumption to consumer's incorrect inferences about caloric content, decreasing guilt or other decision errors. In our framework, over-consumption of less unhealthy goods can happen even when consumers correctly estimate the unhealthiness of goods and is the result of the trade-off between future harm and more immediate gratification.[6] If products are less unhealthy, the future harm is offset by the desire for immediate gratification. In such situations, consumers at the consumption stage would overconsume. However, if products are unhealthier, the increased future harm can no longer be justified by the short-term benefits. Therefore, for such products consumers could exert self-control and consume moderately. In other words, product unhealthiness can act as a self-control device enabling some consumers to consume in moderation. Note that we need to account for strategic response by the firm in terms of prices. Indeed, in the presence of over-consumption by some consumers, firms optimally charge a higher price for less unhealthy goods. This would tend to decrease over-consumption. However, our result shows that even after accounting for this price increase, a decrease in h will lead to more consumers overconsuming vice goods.

Next, we consider the impact of h on consumer harm. Consumer harm is defined by

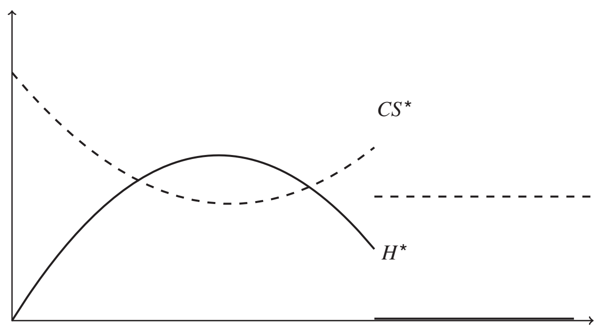
$$\text{Harm} \equiv H = \int_0^{\theta_2} h f(\theta)\, d\theta. \tag{4}$$

Therefore

$$\frac{\partial H}{\partial h} = F(\theta_2) + h f(\theta_2) \cdot \frac{\partial \theta_2}{\partial h}. \tag{5}$$

The first term is positive and represents the direct effect of increase in h on consumer harm for those consumers who are over-consuming. The second effect is the reduction of harm due to fewer people over-consuming. This is composed of a direct effect that decreases over-consumption with an increase in h and an indirect effect through prices as an increase

Figure 2. Overall Harm and Consumer Surplus Under Monopoly: Impulsive Consumers Only



Note. The parameters used for the figure are: $\bar{v} = 2$, $\beta = 0.5$, $c = 0.4$, and θ is uniformly distributed.

in h reduces prices, which tends to encourage over-consumption. Overall, the first part of the proposition shows that over-consumption decreases as h increases. Note that for large h, few consumers overconsume and θ_2 is small. In such cases, the second effect will dominate and overall harm will decrease as h increases (see Figure 2). *In other words, decrease in unhealthiness of vice goods would lead to the unintended consequence of hurting overall public health.*

Now consider the impact of h on CS. An increase in h decreases over-consumption. Therefore, it helps these groups of consumers, not only because they do not overconsume but also because they pay lower prices. An increase in h also helps consumers who consume moderately since they pay lower prices. The only group who is negatively affected by an increase in h are those who continue to overconsume. These consumers benefit from the lower prices but are hurt by the increase in harm from over-consumption. For large h, this group is relatively small and therefore overall CS increases as h increases. These results show that public policy mandating lower sugar, calories or decreasing trans fats could lead to the unintended consequence of decreasing consumer welfare and worsen public health. Similarly, while e-cigarettes could be viewed as healthier alternatives to regular cigarettes, they could lead to increased consumption of nicotine. Indeed, this is the reason that many are arguing for regulation of e-cigarettes (Bravo et al. 2016, Tobacco-Free Kids 2016). Figure 2 shows how consumer harm and surplus change with h. Note that for large values of h, as products become unhealthier consumer health and surplus improve. This is consistent with our proposition. However, note also that the pattern reverses for low values of h. In particular, for low h the increase in unhealthiness hurts the consumers. However, the reverse holds when products are fairly unhealthy. The reason is intricately tied to the fact that an increase in h at high levels of h improves the ability of consumers to exert self-control.

2.2. Competition

Next, we examine the case when there are two firms with Firm 1 at point 0 of the Hotelling line and Firm 2 at point 1. We restrict $f(\cdot)$ to be uniform. If both firms have some consumers who overconsume their products, consumers in $(0, \theta_2)$ overconsume Firm 1's product while consumers in $(\theta_3, 1)$ overconsume Firm 2's product where

$$\theta_2 = \bar{v} - \beta h_1 - p_1, \tag{6}$$

$$\theta_3 = 1 - \bar{v} + p_2 + \beta h_2. \tag{7}$$

We denote the levels of product unhealthiness with h_1 and h_2 and corresponding prices with p_1 and p_2. Consumers in (θ_2, θ_1) buy Firm 1's product and do not overconsume while consumers in (θ_1, θ_3) moderately consume Firm 2's product where

$$\theta_1 = \frac{p_2 - p_1 + 1}{2}. \tag{8}$$

The competitive case can lead to multiple equilibria for some ranges of h. We use the pareto-dominance criterion to select equilibrium in such cases. Because the results of the analysis are similar to those of the monopoly case, we keep the discussion brief. In particular, as before, prices decrease and then increase as h increases. Consistent with the monopoly result, firm's profits decrease with h and fewer consumers overconsume with an increase in h. We also find that for large h and $\bar{v}$, an increase in h leads to improved consumer health and surplus. See Online Appendix A for details.

Although the competitive case leads to similar results as in a monopoly, note that h also affects the level of price competition in the market. In particular, as h decreases, firms can sell two units to consumers who have a strong preference for their products, i.e., on the edges of the Hotelling line. Consumers who are indifferent between the two firms continue to moderately consume. A decrease in price decreases the profits from the segment of consumers who overconsume while potentially increasing the revenues from consumers who moderately consume. As h decreases, the size of the segment who overconsumes increases. Therefore, as h decreases, reducing price becomes less attractive. Because prices are strategic complements, the overall result is that firms can use reduction in product unhealthiness as a strategic tool to reduce price competition.

Finally, consider the case when the firms decide on h. As expected, consistent with previous results, firms choose $h^* < h_e$ (see Online Appendix A for a formal proof). Note that competition could further decrease the incentives for firms to produce unhealthier goods. Note also that the first-order condition for Firm 1 that determines the equilibrium h_1 is

$$\frac{d\Pi_1^*}{dh_1} = \frac{\partial \Pi_1}{\partial h_1} + \frac{\partial \Pi_1}{\partial p_2} \cdot \frac{\partial p_2^*}{\partial h_1} - \mathscr{C}'(h_1). \tag{9}$$

The first part is the monopoly effect and is negative. The second term is the effect of changing h_1 through the strategic impact on Firm 2's prices. Firm 1's prices decline as h_1 increases. Because prices are strategic complements, a decrease in p_1 also decreases Firm 2's price p_2^*. In other words, an increase in h_1 intensifies price competition and leads both firms to reduce prices. Thus, the strategic effect is also negative. Consequently, competition could enhance firms' incentives to invest in healthier products, i.e., firms will choose $h < h_e$.

3. Consumers Preplan

Now we consider the case when consumers can preplan their purchases. If consumers are concerned about over-consumption, they could engage in pre-purchase planning (Hoch and Loewenstein 1991, Nenkov et al. 2008). By planning ahead, consumers may avoid shopping in a store or dining in a restaurant if they foresee that they would make unhealthy food choices and overconsume. To capture this, we assume that α fraction of consumers plan their purchase and $1-\alpha$ fraction do not plan. We refer to the two types of consumers as planners and impulsive consumers. Note that while we assume that there are two distinct segments, an alternate assumption is that there is a probability α that a consumer could be a preplanned buyer and a probability $1-\alpha$ that the same consumer could be an impulsive buyer. The probability α could be related to situational or emotional factors. All our results are valid with this alternative interpretation. We assume that planners and impulsive buyers have the same β parameter.[7]

Let period 0 be the planning stage. In period 0, a planner decides whether to shop for the product by considering the outcome of shopping. In period 1, the planner who decides to shop arrives at the store and decides how much to buy.[8] Impulsive consumers differ from planners in that they skip the planning stage and make the purchase decision directly. If the consumer consumes two units of the product, i.e., if over-consumption happens, the long-term harm occurs in period 2. We will solve the game using backward induction. As in Section 2, we solve the pricing stage of the game to examine the impact of h on equilibrium outcomes and then analyze firms' endogenous choice of h.

Note that consumers in periods 0 and 1 have different preferences. Thus, to make their decisions, consumers must predict their future actions. We assume that consumers form rational expectations about future behavior. 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 whether he will consume one unit or two units in the future. However, casual observation suggests that sometimes consumers may not perfectly anticipate their future actions (see Heidhues and Kőszegi 2010; O'Donoghue and Rabin 2001, 2003). In Online Appendix C we present the analysis for such a case. We find that, by raising prices, firms can exploit planners' naïvete to increase profits. Furthermore, the main results continue to hold even when we allow for naïve expectations.

3.1. Monopoly

We first consider the case of a monopolist. The assumptions are the same as in the base case with impulsive consumers. However, to ensure quasiconcavity of profit functions we assume that $f'' \leq 0$. The analysis for the impulsive consumers is the same as stated earlier. Now, however, we also need to consider the planners' decisions. Planners can choose to avoid shopping if they fear over-consumption. This happens only when $\theta < \theta_2$ where θ_2 is given by $\bar{v} - p - \beta h$ as shown earlier. To consider the case when preplanning is useful we assume that abstention is better than rationally overconsuming. Absent this assumption, there would be no need for preplanning.[9] Note, however, that if we were to interpret α as the probability of being a planner, such consumers will overconsume when they are impulsive buyers. Nevertheless, the result of such planning would be to reduce the frequency of over-consumption. This is consistent with the advice of many weight loss programs which advocate that consumers reduce the frequency with which they eat out or consume vice goods. There is also empirical evidence that an increase in frequency of eating out is partly responsible for the rise in obesity (see Gorgulho et al. 2013, Kant and Graubard 2004).

Note that consumers in (θ_2, θ_1) moderately consume where $\theta_1 = \bar{v} - p$. With this assumption, the profit function for the firm is given by

$$\begin{aligned}\Pi_1 &= \big(\alpha[F(\theta_1) - F(\theta_2)] + (1-\alpha)[F(\theta_1) + F(\theta_2)]\big) \\ &\quad \cdot (p - c), \qquad (10)\\ &= \big[F(\theta_1) + (1-2\alpha)F(\theta_2)\big](p-c). \qquad (11)\end{aligned}$$

It turns out that our results change substantially from the base case when there are sufficient numbers of planners, i.e., when $\alpha > \frac{1}{2}$. Therefore, for the remainder of the paper, we will consider this case. We will, however, dispense with this assumption in Proposition 7 where we explicitly examine the impact of α. We have the following result:

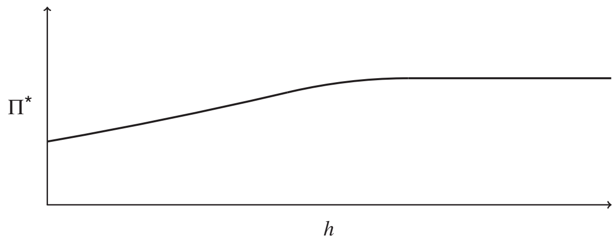
Proposition 4. *If $\alpha > \frac{1}{2}$ then as products become unhealthier*:

(a) *Firm's profits increase.*

(b) *Prices increase and then decrease.*

The proposition shows that the results are substantially different when the market consists of sufficient

Figure 3. Monopolist's Profits Vary with h When $\alpha > \frac{1}{2}$



Note. The parameters used for the figure are: $\bar{v} = 2$, $\beta = 0.5$, $c = 0.4$, and $\alpha = 0.75$, and θ is uniformly distributed.

numbers of planners. Recall that in the absence of planners, the monopolist's profits decrease when its products are unhealthier. By contrast with planners, the monopolist is better off as its products become unhealthier (see Figure 3). Furthermore, prices are an inverted U function of h (see Figure 4). Let us first understand the impact of h on profits. For low levels of h, some impulsive consumers overconsume. However, many planners abstain since they know they will overconsume at the consumption stage. These consumers would, however, be willing to visit the store when they know that they will not overconsume. This could happen when h increases, i.e., when products are unhealthier. Thus, the impact of h on demand from planners and impulsive consumers is the opposite. When there are sufficient numbers of planners, the effect of h in increasing demand dominates and the firm's profits increase as h increases. The key point is that *unhealthiness can act as a self-control device for planners*.

Now consider the impact of h on prices. For low values of h, an increase in h brings in high-valuation planners who were abstaining before. This enables the firm to charge higher prices. However, as h continues to increase, the optimal price is such that no consumer abstains, i.e., $p^* = \bar{v} - \beta h$. In this case, an increase in h reduces the price that the firm can charge. As h continues to increase, no consumers overconsume, and prices do not change with h (see Figure 4). Now, consider how the above results affect the firm's incentives to invest in decreasing the unhealthiness of their products.

Proposition 5. *If $\alpha > \frac{1}{2}$ then the monopolist chooses $h^* > h_e$, if $h_e < \bar{h}$ and chooses $\bar{h}$ otherwise.*

The result shows that when enough consumers preplan, the monopolist may have incentives to invest in making products unhealthier. This suggests that preplanning by consumers can lead to the unintended consequence that firms produce unhealthy products. While this in general would not affect the planners (since they do not overconsume), it could negatively affect the health of impulsive buyers. In other words, planners could exert a negative externality on the health of the impulsive buyers. We formally examine this intuition in the next proposition.

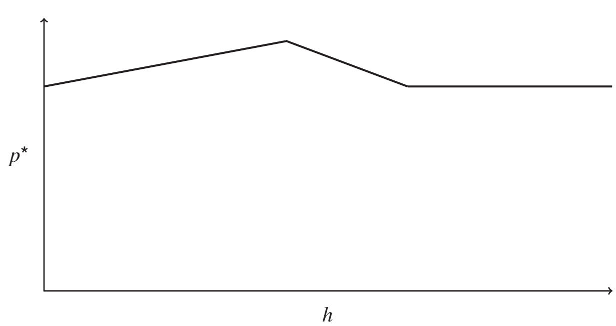
Proposition 6. *If $\alpha > \frac{1}{2}$ then as products become unhealthier*:

(a) *Fewer consumers overconsume.*
(b) *For sufficiently large h, consumer health improves.*
(c) *For large α, CS increases.*

To understand the result, note that over-consumption is an issue only for the impulsive buyers since the planners can control over-consumption by abstaining.[10] For these consumers, an increase in h decreases their tendency to overconsume, which is consistent with our earlier results. The second part of the proposition shows that for large h an increase in h can improve consumer health (see Figure 5). The reason is as stated earlier: A large h implies that relatively few consumers are over-consuming. An increase in h hurts the consumers who overconsume but helps the consumers who switch to moderate consumption due to the increase in h.

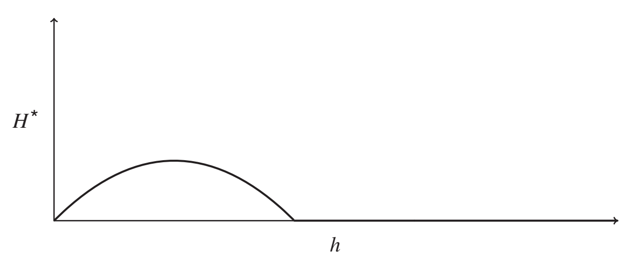
The last part of the proposition shows that in the presence of sufficient numbers of planners, CS could increase with h. To understand this, note that an increase in h affects CS by changing the number of consumers who buy the product and the prices that the consumers pay. When there is some over-consumption, an increase in h decreases over-consumption, which helps CS. Furthermore, it leads to some planners

Figure 4. Monopolist's Prices Vary with h When $\alpha > \frac{1}{2}$



Note. The parameters used for the figure are: $\bar{v} = 2$, $\beta = 0.5$, $c = 0.4$, and $\alpha = 0.75$, and θ is uniformly distributed.

Figure 5. Overall Harm Under Monopoly When $\alpha > \frac{1}{2}$



Note. The parameters used for the figure are: $\bar{v} = 2$, $\beta = 0.5$, $c = 0.4$, and $\alpha = 0.75$, and θ is uniformly distributed.

not abstaining and buying the product. This also increases CS. However, the prices also increase, which hurts CS. Finally, an increase in h hurts the consumers who continue to overconsume. When α is large the last term is small. Furthermore, for concave $F(\cdot)$, the effect of increased demand on CS dominates the negative effect of higher prices. Therefore, in such cases, CS increases as products become unhealthier. The result therefore suggests that making unhealthier products can improve CS when consumers preplan. Proposition 5 shows that this is consistent with the monopolist's incentives, who also chooses not to invest in making products healthier.

Our results so far show that the results are substantially different when we allow some consumers to preplan their purchases. Our results, however, are based on the assumption that $\alpha > \frac{1}{2}$. In the next proposition, we dispense with this restriction on α and show that the directional effect of α is consistent with our results.

Proposition 7. *As α increases*:

(a) *Prices increase but firm's profits decrease.*

(b) *Consumer health improves. Furthermore, if $f(\cdot)$ is uniform and $\alpha < \hat{\alpha}$ then* CS *increases.*[11]

(c) *For uniform $f(\cdot)$, the firm chooses unhealthier products.*

The first part of the proposition shows that as more consumers preplan, prices increase. The intuition is that as more consumers preplan, higher prices provide a commitment to the planners that they will not overconsume. In other words, higher prices can increase demand from planners. The second part of the proposition shows that consumer preplanning can improve health and surplus, even after we consider strategic actions by the firm to account for such preplanning. Finally, the last part of the proposition confirms our earlier analysis and shows that consumer preplanning can lead to firms not investing in making products less unhealthy.

3.2. Competition

Now, we consider the case when both firms compete. Because we are interested in symmetric firms, we assume that the distribution function $f(\cdot)$ is symmetric around $\frac{1}{2}$ and is log-concave. Note that the uniform distribution is a special case of this assumption. Suppose firm i has an unhealthiness level h_i. In this case, if $p_1 < \bar{v} - \beta h_1$, then some consumers would rather abstain than buy from Firm 1. On the other hand, in the impulsive segment some consumers will overconsume Firm 1's product. We define

$$\tilde{\Pi}_1 = F(\theta_1)(p_1 - c). \tag{12}$$

This is the profit function when no consumer abstains or overconsumes. Similarly,

$$\tilde{\Pi}_2 = (1 - F(\theta_1))(p_2 - c). \tag{13}$$

The equilibrium for the profit functions defined in (12) and (13) will be determined by the first-order conditions

$$0 = -\frac{f(\theta_1)}{2}(p_1^* - c) + F(\theta_1), \tag{14}$$

$$0 = \frac{f(\theta_1)}{2}(p_2^* - c) + (1 - F(\theta_1)). \tag{15}$$

Note that log-concavity and symmetry ensure that there is a unique best response function for each firm to other firm's prices. Denote Firm 1's optimal price as a response to Firm 2's price as $\phi_1(p_2)$. Similarly, Firm 2's best response function is denoted by $\phi_2(p_1)$. Since $f(\cdot)$ is symmetric around $\frac{1}{2}$, $\phi_1(\cdot) = \phi_2(\cdot) = \phi(\cdot)$. In this case, if $h_1 = h_2$, then a symmetric pure strategy Nash equilibrium in pricing exists. Let (p^e, p^e) be the equilibrium prices in this case. Also, define $f(\frac{1}{2}) = \hat{f}$. In this case, it is clear that the profits of each firm in the symmetric pricing equilibrium (p^e, p^e) will be $1/(2\hat{f})$.

Now, consider the case when both firms independently decide on the level of harm h_i. To focus on demand side considerations, we assume that $C'(h)$ is negative but small. This assumption means that costs play a small role in our results only to the extent that ceteris paribus firms would prefer to choose a higher h rather than a smaller h. Of course, if the cost to reduce h is high then firms might choose to produce unhealthy goods. We have the following result:

Proposition 8. *Suppose $\alpha > \frac{1}{2} + \hat{f}/(4f(0))$ and $C'(h)$ is small but negative then there are two pure-strategy equilibria for the stage in which firms choose h. These are $(h_e, \bar{h})$ and $(\bar{h}, h_e)$ where*

$$h_e = \arg\max_{h \le h_a} (\bar{v} - \beta h - c) F\left(\frac{1 + \phi(\bar{v} - \beta h) - (\bar{v} - \beta h)}{2}\right) \tag{16}$$

and $h_a = (\bar{v} - c - 1/\hat{f})/\beta$. The profits of both firms are strictly higher than $1/(2\hat{f})$. Furthermore, the firm with a higher h has a higher market share and profits.[12]

This proposition shows that under competition and a relatively flat cost function, firms will be unable to coordinate to a symmetric h when there are a large number of planners. Interestingly, there is an asymmetric equilibrium in which one firm chooses high h and the other produces a lower harm product. This leads to both firms improving their profits relative to the symmetric equilibrium (p^e, p^e). However, the firm that produces the unhealthier product, i.e., that chooses $\bar{h}$, will have lower prices, higher market share, and profits. This result suggests that when there is a sufficient number of planners, competition could increase incentives for one firm to make less unhealthy vice goods while the other firm continues to produce unhealthy products. This result is in contrast to our result in the case of a monopoly with sufficient numbers of planners.

To understand the intuition for this result, note that for a given h, an increase in price affects the impulsive and planned buyers differently. For the impulsive buyers, an increase in price reduces over-consumption and sales. On the other hand, an increase in price reduces the tendency of over-consumption. This in turn reduces the number of planners who abstain and could *increase* sales. If both firms could coordinate, then for sufficiently large α, the demand enhancing effect dominates and each firm finds it optimal to raise prices until over-consumption is eliminated. The price at which this happens is $\bar{v} - \beta h_i$. Note that this implies that the minimum price that each firm charges is decreasing as h increases. This is due to the fact that h and price serve as self-control devices to assure planners that they will not overconsume in the consumption stage. Because firms decide on product design before prices, this implies that if firms reduce harm h then they can commit to charging higher prices. Because prices are strategic complements, reducing harm can mitigate price competition and increase profits. Note that this result is similar to the result in the base case where competition also increases incentives for firms to produce less unhealthy goods. However, the reason is very different. When the market consists only of impulsive buyers, a decrease in unhealthiness makes the product more attractive to the impulsive consumers and reduces incentives for firms to reduce prices. By contrast, when the market consists mostly of planners, then a decrease in unhealthiness could serve as a *coordination device* to reduce price competition. Specifically, if a firm has a low level of h then it must charge higher prices for the planners to buy the product. This enables both firms to charge higher prices. The discussion so far assumes that firms can coordinate. However, such coordination is not possible and the proposition clarifies that only partial coordination occurs in equilibrium. In particular, if one firm chooses a low h then the other firm has an incentive to deviate and charge $\bar{h}$. This enables the deviating firm to charge lower prices and gain higher market share. Nevertheless, even without perfect coordination, firms can make higher profits than they would if they were to charge (p^e, p^e) in the symmetric case. Note that the result only applies when there are a large number of planners. We have already established that when α is low (i.e., $\alpha = 0$ in Section 2), then both firms will choose low h under competition.

4. Model Extensions

Next, we discuss some of the main insights from our analysis and see how relaxing some of the assumptions in our model could change the results. Our results show that the common intuition that firms do not have incentives to produce healthy goods when most consumers have self-control problems is not true. Furthermore, forcing firms to make products healthier could lead to unintended consequences such as poorer consumer health and welfare. We also find that encouraging consumers to preplan their purchases would improve CS and health. However, such preplanning can lead to unhealthier products and higher prices. Now, we discuss how our results could change if we change some of our assumptions.

4.1. Consumers Experience Different Harm from Over-Consumption

In our base case, we assume that consumers have different base valuations for the product. In our analysis, consumers with a strong preference for the product tend to overconsume. However, we assumed that consumers do not vary in terms of the harm that they incur from over-consumption. In Online Appendix D, we consider a model of vertical differentiation in which the harm is modeled as θh where θ is uniformly distributed with range $(\underline{\theta}, \bar{\theta})$. The range of θ is such that all consumers would ex post still prefer not to overconsume. The utility of the consumer in this case from over-consuming, i.e., buying two units is

$$U(\theta) = 2(\bar{v} - p) - \beta\theta h. \tag{17}$$

The consumer will therefore overconsume if $\theta < (\bar{v} - p)/\beta h$. In other words, consumers who care less about the long-term harm are more likely to overconsume. The basic intuition still holds in this alternate framework (see Online Appendix D for details).[13]

4.2. Consumers Can Increase β

Now we consider the case when consumers can resist temptations by focusing on long-term goals. Behavioral research has shown that strategies such as outcome elaboration can be effective in improving self-control (Haws and Nenkov 2012). We assume that a segment η of consumers can exert self-control and do not have self-control problems; that is, $\beta = 1$. Then, the fraction of consumers who cannot exert self-control is $1 - \eta$ and their hyperbolic discounting factor is $\beta < 1$. The consumers who can exert self-control always consume products in moderation.[14] Therefore, the profit function is given by

$$\Pi = \begin{cases} [F(\theta_1) + (1-\eta)F(\theta_2)](p-c) & \text{if } p < \bar{v} - \beta h, \\ F(\theta_1)(p-c) & \text{otherwise.} \end{cases} \tag{18}$$

Since $0 \le \eta \le 1$, comparing this with the case when consumers preplan, we see from (11) that the analysis for firm level decisions would be the same as for the case when $\alpha < \frac{1}{2}$. We find that in this situation firms have lower incentives to produce unhealthy goods and that the firm will charge higher prices. In a competitive setting, we find similar results. Thus, the results show that the two strategies, i.e., improved deliberation and preplanning can lead to a dramatically different impact on firm's incentives to produce healthier goods. In particular, as more consumers preplan, firms will have more incentives to produce unhealthier goods while an increase in β through self-deliberation would incentivize firms to make fewer unhealthy products.

4.3. Consumers May Not Know h

Next, we consider the case when consumers are not fully aware of h. Prior research suggests that consumers often underestimate the harmfulness of vice goods (see, for example, Block et al. 2013). To model this simply, we assume that consumers believe that the future harm is λh where $\lambda \in (0,1]$ and h is the actual harm. In this reformulation, the impact of h follows the pattern we have previously found. However, this raises the question of how λ affects consumer choice, firm's prices, and profits. Furthermore, does the firm have an incentive to disclose truthful information that might reveal that the harmfulness of the product is higher than the consumer perceives? Indeed, several regulations are being proposed to ensure that firms provide such information (see, for example, Wansink and Chandon 2006, Chandon and Wansink 2007).

Consider the case when all consumers are impulsive and the case of monopoly. In this case consumers from $\theta \in (\bar{v} - p - \lambda\beta h, \bar{v} - p)$ moderately consume and consumers with $\theta \in (0, \bar{v} - \lambda\beta h - p)$ overconsume. As λ increases, over-consumption declines. The firm's prices also decline in λ. To see this note that

$$\frac{\partial^2 \Pi}{\partial p \partial \lambda} = \beta h[f'(\tilde{\theta}_2)(p^* - c) - f(\tilde{\theta}_2)] < 0, \qquad (19)$$

where $\tilde{\theta}_2 = \bar{v} - p^* - \lambda\beta h$. Therefore p^* declines (using the implicit function theorem). Note that while λ affects consumer choice, it does not have a direct effect on consumer health and surplus. However, since higher λ decreases over-consumption and leads to reduced prices, consumer health and surplus would be positively affected when consumers are more accurately aware of the harm from over-consumption. Note, however, that firm's profits will decline and therefore firms may not have the proper incentives to truthfully disclose this information. Also, firms will have higher incentives to invest in making products less unhealthy. This is consistent with the objectives of public policy makers.

However, things could change when we consider the presence of planners. In particular, consumers with $\theta \in (0, \tilde{\theta}_2)$ abstain. As λ increases, fewer consumers abstain. This in turn enables the firm to charge higher prices and make higher profits. Interestingly, this suggests that firms could benefit by providing planners with information about the true value of h. Because planners make their purchasing decisions before entering the store, firms could benefit by providing nutritional information online. Of course, if we interpret α in our model as the proportion of times that consumers plan, then consumers could also get nutritional information at the point-of-purchase and could use this information for later planned purchases. This implies that the impact of providing nutritional information on sales depends on the proportion of planners and impulsive buyers. Better information could increase sales from planners while reducing sales from impulsive consumers. Indeed, studies on the impact of information on sales of vice goods have found mixed results (see, for example, Elbel et al. 2009, Harnack et al. 2008, Finkelstein and Fishbach 2010, Finkelstein et al. 2011).

4.4. Taste and h May Be Correlated

Consider the situation in which unhealthier products are perceived to be more tasty (see, for example, Raghunathan et al. 2006). To model this simply, we assume that the maximum utility that a consumer could get is $\bar{v} + \tau(h)$ where $h > \tau(h) \geq 0$ and $\tau'(\cdot) > 0$. First, consider the impact of h. When the market consists only of impulsive consumers, then for a monopolist the impact of h on profits can be obtained using the envelope theorem. We have

$$\begin{aligned}\frac{\partial \Pi^*}{\partial h} &= \big[f(\bar{v} + \tau(h) - p^* - \beta h)(\tau'(h) - \beta) \\ &\qquad + f(\bar{v} + \tau(h) - p^*)\tau'(h)\big](p^* - c), \qquad (20)\\ &\leq f(\bar{v} + \tau(h) - p^* - h)(p^* - c)[2\tau'(h) - \beta]. \qquad (21)\end{aligned}$$

Therefore, as long as the taste effect is not too large, i.e., $\tau'(h) < \beta/2$, the earlier results would hold. However, when impulsive consumers have a high degree of self-control problems, i.e., when β is small, the perceived taste unhealthiness correlation could reverse the incentives for the firm to produce fewer unhealthy goods. Similarly, consider the impact of h on planners. The perceived taste healthiness correlation increases the value of $\tau(h)$ for higher levels of h and therefore could make more consumers abstain from purchasing the product. As long as $\tau(h)$ is small, the results from our earlier analysis hold. For large $\tau(h)$ the results change. Nevertheless, the insight from our analysis that consumer planning would significantly impact firm's incentives to produce fewer unhealthy goods continues to hold.

5. Conclusion

Obesity has become a worldwide concern for consumers, firms, and public policy makers. Our paper examines how firms selling vice goods should respond to the growing concern about over-consumption of such goods. A firm can adjust prices and change product nutrition. We study these firm strategies when firms sell vice goods to consumers. We also investigate the implications of public education programs that help consumers make a prepurchase plan for a firm's incentive to improve nutrition, profits, CS, and public health. To address these issues, we develop an analytical model that incorporates impulsive consumers as well as consumers who can avoid over-consumption by planning in advance whether to shop for the vice good. Consumers' tendency to avoid over-consumption has important implications on firm's optimal pricing and product design decisions, which in turn impacts CS and long-term health. Our results provide insights into the following questions:

1. *How does product unhealthiness affect firm's profits and prices*? Our results suggest that the impact depends on the number of consumers who preplan. When most consumers are impulsive buyers, the unhealthiness of products would have an impact similar to that of reduced quality. In particular, firms' prices and profits would decrease with unhealthier products. However, if there is a large proportion of consumers who are more health conscious and who preplan, firms selling *unhealthier* products can charge higher prices and make more profits. This result does not depend on any perceived correlation between health and taste of products. Instead, the results are driven by consumers who strategically regulate shopping for fear of over-consumption. Unhealthier products allow such consumers to control consumption at the point of purchase, and therefore induce them to shop for the product and consume it moderately. Furthermore, as more high-valuation consumers stop avoiding purchase, average willingness to pay for the product increases and firms can raise prices. These results establish a unique role of lower product quality as a self-control device in the context of vice goods.

2. *How does increasing pre-purchase planning affect firms and consumers*? We find that as more consumers begin to plan shopping to avoid over-consumption, firms should react by increasing prices of their vice goods because a higher price can allow consumers to consume the product moderately. This result reveals a unique role of higher prices as another self-control device in the context of vice goods. Pre-purchase planning increases public health and CS at the cost of decreasing firm's profits. Furthermore, firms have stronger incentives to produce unhealthier products when more consumers start to pre-plan. Therefore, when public policy makers invest heavily in educational programs that train consumers to regulate purchase and consumption, such efforts may lead to higher prices of vice goods and motivate firms to produce unhealthier products.

3. *How does product unhealthiness affect* CS *and long-term health*? Our results show that sometimes unhealthier products can improve consumers' long-term health and CS. Therefore, for the purpose of improving public health and reducing obesity, requiring firms to reduce harm by reducing ingredients such as trans fat and sugar may exacerbate the problem.

4. *How does competition affect firm's incentives to produce unhealthier products*? Our results suggest that when firms face competition, the strategic effect usually discourages firms from producing unhealthier products. When most consumers are impulsive buyers, a decrease in unhealthiness enables firms to charge higher prices. On the other hand, when there are a large number of planners, firms can use a reduction in unhealthiness as a coordination device to reduce price competition.

These results show that public policy makers should consider strategic response by consumers and firms to changes in policies. These strategic responses can often lead to unintended adverse consequences of regulations. For firms and restaurants that serve vice goods, the increasing pursuit of a healthy diet and changes in consumers' self-regulation behaviors may provide new opportunities to charge higher prices and increase profits.

This paper finds that a decrease in quality and an increase in prices of vice goods can serve as self-control devices and can sometimes increase demand. We also find that when consumers preplan, firms can use a reduction in product unhealthiness as a coordination device to reduce price competition. Although the focus of our analysis is in the domain of vice food products, self-control problems exist in a variety of contexts such as financial decision making, effort allocation, and others. Firms could use such self-control and commitment devices in other contexts and improve profits. Future research could explore this issue. Researchers could also empirically test the impact of product unhealthiness and prices on demand, and explore how consumers' self-control moderates this relationship.

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Appendix

Derivation of Optimal Price When Some Consumers Plan

First we establish the optimal prices for the case when there are α proportion of planners. The base case when there are no planners is a special case with $\alpha = 0$. Note that in this derivation, we consider the case $\alpha \geq \frac{1}{2}$ and also the case $\alpha < \frac{1}{2}$. If $p < \bar{v} - \beta h$, then the monopolist's profit function is

$$\begin{aligned}\Pi_1(p < \bar{v} - \beta h) &= \big[\alpha(F(\theta_1) - F(\theta_2)) \\ &\quad + (1-\alpha)(F(\theta_1) + F(\theta_2))\big](p - c) \qquad \text{(A.1)} \\ &= [F(\theta_1) + (1 - 2\alpha)F(\theta_2)](p - c) \equiv \Pi_1. \qquad \text{(A.2)}\end{aligned}$$

The monopolist's profit function is

$$\Pi(p)=\begin{cases}[F(\theta_1)+(1-2\alpha)F(\theta_2)](p-c) & \text{if } p<\bar{v}-\beta h,\\ F(\theta_1)(p-c) & \text{if } p\in(\bar{v}-\beta h,\bar{v}),\\ 0 & \text{otherwise.}\end{cases} \tag{A.3}$$

Denote $\Pi_2 \equiv F(\theta_1)(p-c)$. Let p_2^* maximize Π_2 and p_1^* be the price that maximizes Π_1 in the range $[c,\bar{v}-\beta h)$. We show below that these are unique. Given that the monopolist chooses from a compact set $[c,\bar{v}]$ and that the profit function is continuous everywhere, from Weierstrass's extreme value theorem, we know that an optimal p^* exists. We now establish the optimal price via a series of claims.

Claim 1. *Π_1 is quasiconcave for $p\in[c,\bar{v}-\beta h)$ and Π_2 is concave for $p\in(c,\bar{v})$. Therefore, p_1^* and p_2^* are unique.*

Proof. First consider Π_2. We have

$$\frac{\partial\Pi_2}{\partial p}=-f(\theta_1^*)(p_2^*-c)+F(\theta_1^*), \tag{A.4}$$

$$\frac{\partial^2\Pi_2}{\partial p^2}=-2f(\theta_1^*)+f'(\theta_1^*)(p_2^*-c)<0, \tag{A.5}$$

where the inequality follows since $f'\le 0$. Now, consider Π_1. If this function is monotonic, then it is clearly quasiconcave. If not, then suppose there is a point at which $\partial\Pi_1/\partial p=0$. The first-order condition for Π_1 is

$$\frac{\partial\Pi_1}{\partial p}=-[f(\theta_1^*)-(2\alpha-1)f(\theta_2^*)](p_1^*-c)+[(F(\theta_1^*)-(2\alpha-1)F(\theta_2^*)]=0. \tag{A.6}$$

The second-order condition is

$$\frac{\partial^2\Pi_1}{\partial p^2}=-2[f(\theta_1^*)-(2\alpha-1)f(\theta_2^*)]+[f'(\theta_1^*)-f'(\theta_2^*)(2\alpha-1)](p_1^*-c) \tag{A.7}$$

$$\le -2[f(\theta_1^*)-(2\alpha-1)f(\theta_2^*)]. \tag{A.8}$$

Note that the inequality holds when $\alpha<\frac{1}{2}$. For $\alpha>\frac{1}{2}$ the inequality follows using $f''(\cdot)\le 0$ and the fact that $\theta_2^*\le\theta_1^*$. Using (A.6) we have

$$[f(\theta_1^*)-(2\alpha-1)f(\theta_2^*)](p_1^*-c)=[(F(\theta_1^*)-(2\alpha-1)F(\theta_2^*)] \tag{A.9}$$

$$\ge F(\theta_1^*)-F(\theta_2^*)>0. \tag{A.10}$$

Using (A.8) and (A.10) establishes that $\partial^2\Pi_1/\partial p^2<0$ at p_1^* which therefore establishes quasiconcavity. □

Claim 2. *The profit function is differentiable everywhere for $p\in(c,\bar{v})$ except at $p=\bar{v}-\beta h$. Furthermore,*

$$\lim_{p\uparrow\bar{v}-\beta h}\frac{\partial\Pi}{\partial p}>\lim_{p\downarrow\bar{v}-\beta h}\frac{\partial\Pi}{\partial p}, \tag{A.11}$$

iff $\alpha>\frac{1}{2}$.

Proof. It is clear that given that the profit function is differentiable everywhere except at $\bar{v}-\beta h$, we only need to show the last part. Define $\hat{f}=\lim_{x\uparrow 0}f(x)>0$. We have

$$\lim_{p\uparrow\bar{v}-\beta h}\frac{\partial\Pi_1}{\partial p}=-[f(\beta h)-(2\alpha-1)\hat{f}](\bar{v}-\beta h-c)+F(\beta h) \tag{A.12}$$

$$=\lim_{p\downarrow\bar{v}-\beta h}\frac{\partial\Pi_2}{\partial p}+(2\alpha-1)\hat{f}(\bar{v}-\beta h-c), \tag{A.13}$$

which proves the claim. □

Claim 3. *If $\alpha>\frac{1}{2}$ then the profit function is quasiconcave for $p\in(c,\bar{v})$. Therefore, if there exists a $p_1^*\in(c,\bar{v}-\beta h)$ then $p_1^*=p^*$.*

Proof. Using Claim 1, we only need to show that if the profit function is decreasing at $p=\bar{v}-\beta h-\epsilon$ it is also decreasing at $p=\bar{v}-\beta h+\epsilon$. However, this immediately follows from Claim 2. □

Claim 4. *If $\alpha>\frac{1}{2}$ then the optimal prices are characterized as follows:*

Case 1. If $\lim_{p\uparrow\bar{v}-\beta h}\partial\Pi_1/\partial p<0$ then $p^*=p_1^*$ and $\theta_2(p^*)>0$.
Case 2. If $\lim_{p\downarrow\bar{v}-\beta h}\partial\Pi_2/\partial p>0$ then $p^*=p_2^*$ and $\theta_2(p^*)<0$.
Case 3. If $\lim_{p\uparrow\bar{v}-\beta h}\partial\Pi_1/\partial p>0>\lim_{p\downarrow\bar{v}-\beta h}\partial\Pi_2/\partial p$ then $p^*=\bar{v}-\beta h\equiv p_3^*$ and $\theta_2(p^*)=0$.

Proof. The first part follows directly from Claim 3. The second part follows since, if $\lim_{p\downarrow\bar{v}-\beta h}\partial\Pi_2/\partial p>0$, this implies that $\lim_{p\uparrow\bar{v}-\beta h}\partial\Pi_1/\partial p>0$ from Claim 2. The last part follows since the conditions for Case 3 lead to a kink in the profit function at $p=\bar{v}-\beta h$ and the function reaches the maximum at this point. □

Claim 5. *If $\alpha>\frac{1}{2}$ then there exist $\hat{h}_1$, $\hat{h}_2$ such that*

$$p^*=\begin{cases}p_1^* & \text{if } h\le\hat{h}_1,\\ \bar{v}-\beta h & \text{if } h\in(\hat{h}_1,\hat{h}_2],\\ p_2^* & \text{if } h>\hat{h}_2.\end{cases} \tag{A.14}$$

Proof. To see this first note that

$$\frac{\partial^2\Pi_1}{\partial p_1\partial h}=\beta(2\alpha-1)[f(\theta_2)-f'(\theta_2)(p-c)]>0. \tag{A.15}$$

Therefore, as h increases, $\partial\Pi_1/\partial p_1$ increases. Furthermore, $\bar{v}-\beta h$ decreases in h and therefore there must exist an $\hat{h}_1$ such that for $h>\hat{h}_1$, $p_1^*\notin(c,\bar{v}-\beta h)$; therefore, for $h\le\hat{h}_1$, Case 1 applies. Note that p_2^* is independent of h and therefore, there exists an $\hat{h}_2$ such that if $h>\hat{h}_2$, $p_2^*>\bar{v}-\beta\hat{h}_2$. In particular, $\hat{h}_1$ and $\hat{h}_2$ are implicitly defined by the equations

$$0=\lim_{p\uparrow\bar{v}-\beta\hat{h}_1}\frac{\partial\Pi_1}{\partial p}=-[f(\beta\hat{h}_1)-(2\alpha-1)\hat{f}](\bar{v}-\beta\hat{h}_1-c)+F(\beta\hat{h}_1), \tag{A.16}$$

$$0=\lim_{p\downarrow\bar{v}-\beta\hat{h}_2}\frac{\partial\Pi_2}{\partial p}=F(\beta\hat{h}_2)-f(\beta\hat{h}_2)(\bar{v}-\beta\hat{h}_2-c). \tag{A.17}$$

From Claim 4 it follows that $\hat{h}_1\le\hat{h}_2$; therefore, for $h\in(\hat{h}_1,\hat{h}_2]$, Case 3 applies. □

Claim 6. *The critical point $\hat{h}_1$ decreases in α. Also, $\hat{h}_2$ is independent of α.*

Proof. The equation that defines $\hat{h}_1$ is given by

$$\Omega_1(\hat{h}_1)=-[f(\beta\hat{h}_1)-(2\alpha-1)\hat{f}](\bar{v}-\beta h-c)+F(\beta\hat{h}_1)=0. \tag{A.18}$$

We have

$$\frac{\partial\Omega_1}{\partial h}=\beta[2f(\beta h)-(2\alpha-1)\hat{f}]-\beta f'(\beta h)(\bar{v}-\beta h-c) \tag{A.19}$$

$$\ge\beta[2f(\beta h)-(2\alpha-1)\hat{f}]$$

$$=\beta\left[2f(\beta h)-f(\beta\hat{h}_1)+\frac{F(\beta\hat{h}_1)}{\bar{v}-\beta\hat{h}_1-c}\right]>0, \tag{A.20}$$

where the last inequality follows since $h \le \hat{h}_1$ and $f' \le 0$. Also

$$\frac{\partial \Omega_1}{\partial \alpha} = 2\hat{f}(\beta \hat{h}_1 - c) > 0. \tag{A.21}$$

Using the implicit function theorem it follows that

$$\frac{\partial \hat{h}_1}{\partial \alpha} = -\frac{2\hat{f}(\beta \hat{h}_1 - c)}{\partial \Omega_1 / \partial h} < 0. \tag{A.22}$$

The equation that defines $\hat{h}_2$ is given by

$$\Omega_2(\hat{h}_2) = F(\beta \hat{h}_2) - f(\beta \hat{h}_2)(\bar{v} - \beta \hat{h}_2 - c) = 0. \tag{A.23}$$

We have

$$\frac{\partial \Omega_2}{\partial h} = 2\beta f(\beta \hat{h}_2) - \beta f'(\beta \hat{h}_2)(\bar{v} - \beta \hat{h}_2 - c) > 0, \tag{A.24}$$

$$\frac{\partial \Omega_2}{\partial \alpha} = 0. \tag{A.25}$$

The result follows from the implicit function theorem. □

Claim 7. *If $\alpha < \frac{1}{2}$ then the optimal price $p^* \ne \bar{v} - \beta h$.*

Proof. For $p^* = \bar{v} - \beta h$ we would need $\lim_{p \uparrow \bar{v} - \beta h} \partial \Pi_1 / \partial p > 0 > \lim_{p \downarrow \bar{v} - \beta h} \partial \Pi_2 / \partial p$. However, this is ruled out by Claim 2. □

Claim 8. *If $\alpha < \frac{1}{2}$ then there exists $\hat{h}_3$ such that*

$$p^* = \begin{cases} p_1^* & \text{if } h \le \hat{h}_3, \\ p_2^* & \text{if } h > \hat{h}_3. \end{cases} \tag{A.26}$$

Proof. When $\alpha < \frac{1}{2}$, p_1^* or p_2^* can be the optimal solution. If both are in the feasible region, then the optimal price is the one that maximizes the profits globally. Therefore, for $\alpha < \frac{1}{2}$, only Cases 1 and 2 as defined in Claim 4 are relevant. Note that from the envelope theorem, if Case 1 applies then

$$\frac{\partial \Pi_1^*}{\partial h} = -(p_1^* - c) f(\theta_2^*) \beta (1 - 2\alpha) < 0. \tag{A.27}$$

Note that Π_2^* is independent of h. Furthermore, from the profit function it is clear that for $\alpha < \frac{1}{2}$, $\Pi_1 > \Pi_2 \; \forall \, p \in (c, \bar{v} - \beta h)$. Therefore, for low values of h such that $p^* < \bar{v} - \beta h$, Π_1 dominates and will intersect Π_2 from above at some critical point $\hat{h}_3$. □

Claim 9. *The critical value $\hat{h}_3$ is decreasing in α.*

Proof. The critical value $\hat{h}_3$ is defined such that $\Pi_1^* = \Pi_2^*$. Note that Π_2^* is independent of α. Also, using the envelope theorem

$$\frac{\partial \Pi_1^*}{\partial \alpha} = -2F(\theta_2^*)(p_1^* - c) < 0. \tag{A.28}$$

Also

$$\frac{\partial}{\partial h}(\Pi_1^* - \Pi_2^*) = -\beta(1 - 2\alpha)(p_1^* - c) f(\theta_2^*) < 0. \tag{A.29}$$

Using the implicit function theorem, it follows that $\hat{h}_3$ decreases in α and β. □

The following claim is useful for several proofs.

Claim 10. *Let $\Pi_0 = F(\theta_2)(p - c)$ then if Case 1 applies then $\partial \Pi_0 / \partial p|_{p_1^*} < 0$.*

Proof. If p_1^* is optimal then we have

$$\frac{\partial \Pi_1}{\partial p} = \frac{\partial \Pi_2}{\partial p} + (1 - 2\alpha)\frac{\partial \Pi_0}{\partial p} = 0. \tag{A.30}$$

First note that

$$\frac{\partial \Pi_2}{\partial p} - \frac{\partial \Pi_0}{\partial p} = F(\theta_1) - F(\theta_2) - (p - c)[f(\theta_1) - f(\theta_2)] > 0. \tag{A.31}$$

Therefore, if the claim is not true, then we must have

$$\begin{aligned} \left.\frac{\partial \Pi_1}{\partial p}\right|_{p_1^*} &= \left.\frac{\partial \Pi_2}{\partial p}\right|_{p_1^*} - (2\alpha - 1)\left.\frac{\partial \Pi_0}{\partial p}\right|_{p_1^*} \\ &> \left.\frac{\partial \Pi_2}{\partial p}\right|_{p_1^*} - \left.\frac{\partial \Pi_0}{\partial p}\right|_{p_1^*} > 0, \end{aligned} \tag{A.32}$$

which violates the requirement that p_1^* is an interior solution. □

Proof of Proposition 1. Note that the optimal solutions in this case can be obtained by setting $\alpha = 0$ in the analysis with some planners. The firm's profits are given by

$$\Pi = \begin{cases} [F(\theta_1) + F(\theta_2)](p - c) & \text{if } p < \bar{v} - \beta h, \\ F(\theta_1)(p - c) & \text{otherwise.} \end{cases} \tag{A.33}$$

Note that for $p = p_2 > \bar{v} - \beta h$, prices and profits are independent of h. For the case when $p = p_1 < \bar{v} - \beta h$, by the envelope theorem

$$\frac{\partial \Pi^*}{\partial h} = -f(\theta_2^*)\beta(p_1^* - c) < 0. \tag{A.34}$$

Thus, profits decrease with h. Also, note that for $p_1 < \bar{v} - \beta h$, we have

$$\frac{\partial^2 \Pi}{\partial p_1 \partial h} = -\beta f(\theta_2) + \beta f'(\theta_2)(p_1 - c) < 0, \tag{A.35}$$

where the inequality follows since $f' \le 0$. The second-order condition is

$$\begin{aligned} \frac{\partial^2 \Pi}{\partial p_1^2} &= -2[f(\theta_1) + f(\theta_2)] \\ &\quad + (f'(\theta_1) + f'(\theta_2))(p_1 - c) < 0. \end{aligned} \tag{A.36}$$

Using the results of Claim 9 in the Online Appendix and the implicit function theorem it follows that if $h \le \hat{h}_3$ then prices are decreasing in h. However, from Claim 9 we know that if $h > \hat{h}_3$ then prices change discontinuously from p_1^* to p_2^*. Also, since $\lim_{h \downarrow 0} p_1^* = \lim_{h \downarrow 0} p_2^*$, it follows that $p_2^* > p_1^*$. Therefore, prices first decrease and then increase as h increases (see Figure 1).

Now, consider total sales. If $h \le \hat{h}_3$, total sales are given by $F(\theta_1^*) + F(\theta_2^*)$. We have

$$\begin{aligned} \frac{\partial}{\partial h}(F(\theta_1^*) + F(\theta_2^*)) &= f(\theta_1^*) \cdot \frac{\partial \theta_1^*}{\partial h} + f(\theta_2^*) \cdot \frac{\partial \theta_2^*}{\partial h} \\ &= -f(\theta_1^*) \cdot \frac{\partial p_1^*}{\partial h} - f(\theta_2^*)\left[\beta + \frac{\partial p^*}{\partial h}\right] \qquad \text{(A.37)} \\ &= -\frac{\partial p_1^*}{\partial h}[f(\theta_1^*) + f(\theta_2^*)] - \beta f(\theta_2^*). \qquad \text{(A.38)} \end{aligned}$$

Using the implicit function theorem, we have

$$\begin{aligned} \frac{\partial p_1^*}{\partial h} &= \frac{-\beta[f(\theta_2^*) - f'(\theta_2^*)(p_1^* - c)]}{2(f(\theta_1^*) + f(\theta_2^*)) - (f'(\theta_1^*) + f'(\theta_2^*))(p^* - c)} \\ &= -\beta\kappa. \end{aligned} \tag{A.39}$$

where $0<\kappa<1$. Furthermore, if $f''\le 0$ then $0<\kappa<\frac{1}{2}$. Therefore from (A.38) it follows that

$$\frac{\partial}{\partial h}(F(\theta_1^*)+F(\theta_2^*))=\beta[\kappa f(\theta_1^*)+(\kappa-1)f(\theta_2^*)] < \frac{\beta}{2}[f(\theta_1^*)-f(\theta_2^*)]\le 0. \quad \text{(A.40)}$$

In addition, $\lim_{h\uparrow\hat{h}_3}F(\theta_1^*)+F(\theta_2^*)=F(\bar{v}-p_1)>\lim_{h\downarrow\hat{h}_3}F(\bar{v}-p_1)$ as $\lim_{h\uparrow\hat{h}_3}p_1^*<\lim_{h\downarrow\hat{h}_3}p_2^*$. Therefore, at $h=\hat{h}_3$, total sales discontinuously decreases with h. If $h>\hat{h}_3$, total sales are independent of h. Therefore, total sales weakly decrease with h. □

Proof of Proposition 2. The firm chooses h to maximize its profit. The relevant first-order condition is $-\beta f(\theta_2^*)(p^*-c)-\mathscr{C}'(h^*)=0$. The result follows since $\mathscr{C}'(h_e)=0$ and $\mathscr{C}(\cdot)$ is convex in h. □

Proof of Proposition 3. If $h\le\hat{h}_3$, $F(\theta_2^*)$ consumers overconsume. We have $\partial F(\theta_2^*)/\partial h=f(\theta_2^*)[-\partial p_1^*/\partial h-\beta]$. Using (A.39) in the online appendix, it follows that $\partial F(\theta_2^*)/\partial h=f(\theta_2^*)[\kappa\beta-\beta]<0$. If $h>\hat{h}_3$, no consumers overconsume. Therefore, overconsumption weakly decreases with h.

If $h\le\hat{h}_3$, overall consumer harm is

$$H=\int_0^{\theta_2^*}hf(\theta)\,d\theta. \quad \text{(A.41)}$$

Therefore

$$\frac{\partial H}{\partial h}=F(\theta_2^*)+h\frac{\partial F(\theta_2^*)}{\partial h}. \quad \text{(A.42)}$$

The first term is positive and the second is negative. We know that as h increases, θ_2^* decreases. Therefore, there must exist an $\hat{h}$ such that θ_2^* approaches 0 and therefore the overall term is negative for $h\in(\hat{h},\hat{h}_3]$. If $h>\hat{h}_3$, $H=0$. Therefore, H weakly decreases with h.

If $h\le\hat{h}_3$, CS is defined by

$$\mathrm{CS}=\int_0^{\theta_2^*}[2(\bar{v}-p_1^*-\theta)-h]f(\theta)\,d\theta+\int_{\theta_2^*}^{\theta_1^*}(\bar{v}-p_1^*-\theta)f(\theta)\,d\theta. \quad \text{(A.43)}$$

Therefore

$$\begin{aligned}\frac{\partial\,\mathrm{CS}}{\partial h}&=-\left(2\frac{\partial p_1^*}{\partial h}+1\right)F(\theta_2^*)+(\bar{v}-\theta_2^*-p_1^*-h)f(\theta_2^*)\frac{\partial\theta_2^*}{\partial h}\\&\quad-\frac{\partial p_1^*}{\partial h}[F(\theta_1^*)-F(\theta_2^*)]\\&=-F(\theta_2^*)(1-\beta\kappa)-\frac{\partial p_1^*}{\partial h}F(\theta_1^*)\\&\quad+f(\theta_2^*)(1-\beta)h\beta(1-\kappa),\end{aligned} \quad \text{(A.44)}$$

where the last equality follows using (A.39). The last two terms are positive and the first term approaches 0 for sufficiently large h.

If $h>\hat{h}_3$, CS is independent of h and given below

$$\mathrm{CS}=\int_0^{\theta_1^*}(\bar{v}-p_2^*-\theta)f(\theta)\,d\theta. \quad \text{(A.45)}$$

Given that $\lim_{h\uparrow\hat{h}_3}p_1^*=\bar{v}-\beta h<\lim_{h\downarrow\hat{h}_3}p_2^*$, we have that

$$\lim_{h\uparrow\hat{h}_3}\mathrm{CS}=\int_0^{\beta h}(\beta h-\theta)f(\theta)\,d\theta>\lim_{h\downarrow\hat{h}_3}\mathrm{CS}=\int_0^{\bar{v}-p_2^*}(\bar{v}-p_2^*-\theta)f(\theta)\,d\theta. \quad \text{(A.46)}$$

Therefore, as h increases to $h=\hat{h}_3$, CS discontinuously decreases. As a result, as h increases, for a large h, CS increases and then discontinuously decreases (see Figure 2). □

Proof of Proposition 4. Consider the impact of h on prices and profits. If $h<\hat{h}_1$, p_1^* is the optimal solution and Case 1 applies. Using the envelope theorem we have

$$\frac{\partial\Pi_1^*}{\partial h}=(2\alpha-1)\beta f(\theta_2)(p_1^*-c)>0. \quad \text{(A.47)}$$

For $h\in(\hat{h}_1,\hat{h}_2)$, Case 3 applies and $p^*=\bar{v}-\beta h$ and the profit function is

$$\Pi_3^*=F(\beta h)(\bar{v}-\beta h-c). \quad \text{(A.48)}$$

This implies that

$$\begin{aligned}\frac{\partial\Pi_3^*}{\partial h}&=-\beta[F(\beta h)-(\bar{v}-\beta h-c)f(\beta h)]\\&=-\beta\frac{\partial\Pi_2}{\partial p}\Big|_{p=\bar{v}-\beta h}>0.\end{aligned} \quad \text{(A.49)}$$

The inequality follows, since in this case $p_1^*<\bar{v}-\beta h$. If $h>\hat{h}_2$, Π_2^* applies and is independent of h.

Now consider prices. When $h<\hat{h}_1$, Case 1 applies. Therefore, using (A.15) and the quasiconcavity of the profit function and the implicit function theorem, it follows that prices are increasing in h. If $h\in(\hat{h}_1,\hat{h}_2)$, $p^*=\bar{v}-\beta h$ which is clearly decreasing in h. If $h>\hat{h}_2$ then prices are independent of h. Therefore, prices first increase and then decrease, which is an inverted-U shape of h. □

Proof of Proposition 5. Equations (A.47) and (A.48) show that profits over the region that $h<\hat{h}_2$ increase with h. For $h>\hat{h}_2$, profits are independent of h. The result follows since $\mathscr{C}'(h_e)=0$. □

Proof of Proposition 6. We have $\partial\theta_2^*/\partial h=-\beta-(\partial p_1^*/\partial h)<0$, where the inequality follows from the result in Proposition 4 that $\partial p_1^*/\partial h>0$. Let H denote the total intake of harm by consumers. Note that only in Case 1, impulsive consumers whose $\theta<\theta_2$ overconsume and incur the harm. Hence, $H>0$ for $h<\hat{h}_1$ where Case 1 applies and $H=0$ for $h>\hat{h}_1$ where Cases 2 and 3 apply. In Case 1, the overall intake of harm is

$$H=(1-\alpha)hF(\theta_2^*), \quad \text{(A.50)}$$

$$\frac{\partial H}{\partial h}=(1-\alpha)\left[F(\theta_2^*)+\frac{\partial\theta_2^*}{\partial h}hf(\theta_2^*)\right]. \quad \text{(A.51)}$$

At $h=\hat{h}_1$, $\theta_2^*=0$ and $H(\hat{h}_1)=0$. Furthermore,

$$\frac{\partial H}{\partial h}\Big|_{h=\hat{h}_1}=(1-\alpha)\left[\frac{\partial\theta_2^*}{\partial h}\cdot\hat{h}_1f(\theta_2^*)\right]<0. \quad \text{(A.52)}$$

Because the consumer incurs some harm in the region $(\underline{h},\hat{h}_1)$, and the function is continuous, it implies that there must exist a $\tilde{h}\in[\underline{h},\hat{h}_1)$ such that $H(\cdot)$ is decreasing in this region.

Now consider CS. We have

$$\mathrm{CS}=\int_{\theta_2^*}^{\theta_1^*}(\bar{v}-p^*-\theta)f(\theta)\,d\theta+(1-\alpha)\int_0^{\theta_2^*}(2\bar{v}-2p^*-h-2\theta)f(\theta)\,d\theta. \quad \text{(A.53)}$$

Therefore

$$\begin{aligned}\frac{\partial \mathrm{CS}}{\partial h} &= -\frac{\partial p^*}{\partial h}[F(\theta_1^*)-F(\theta_2^*)] - \frac{\partial \theta_2^*}{\partial h}[\bar{v}-p^*-\theta_2^*]f(\theta_2^*) \\ &\quad + (1-\alpha)\left[\frac{\partial \theta_2^*}{\partial h}(2\bar{v}-2p^*-h-2\theta_2^*)f(\theta_2^*) \right.\\ &\qquad \left. + \int_0^{\theta_2^*}\left(-2\cdot\frac{\partial p^*}{\partial h}-1\right)f(\theta)\,d\theta\right] \qquad \text{(A.54)}\\ &= \frac{\partial p^*}{\partial h}\cdot[\beta h f(\theta_2^*)+F(\theta_2^*)-F(\theta_1^*)] - \beta h f(\theta_2^*)\frac{\partial \theta_2^*}{\partial h} \\ &\quad - (1-\alpha)\left[\left(\beta+\frac{\partial p^*}{\partial h}\right)f(\theta_2^*)(2\bar{v}-2p^*-h-2\theta_2^*) \right.\\ &\qquad \left. - F(\theta_2^*)\left(2\frac{\partial p^*}{\partial h}+1\right)\right]. \qquad \text{(A.55)}\end{aligned}$$

Note that concavity of $F(\cdot)$ implies that $(F(\theta_1^*)-F(\theta_2^*))/f(\theta_2^*) \le \theta_1^*-\theta_2^* = \beta h$. Therefore, the first term in (A.55) is positive. For large α therefore, the overall term will be positive. □

Proof of Proposition 7. Note that α only impacts firm decisions in Case 1. We show that profits in Case 1 decrease with α. By the envelope theorem

$$\frac{\partial \Pi_1^*}{\partial \alpha} = -2(p_1^*-c)F(\theta_2^*) < 0. \qquad \text{(A.56)}$$

Note however that when $\alpha > \frac{1}{2}$, $\hat{h}_1$ is also a function of α. In particular, we know from Claim 6 that h_1^* decreases as α increases and h_2^* is independent of α. Because the relationship is monotonic this implies that we can define an $\hat{\alpha}_1$ such that Case 1 applies only if $\alpha < \hat{\alpha}_1$. If $\alpha > \hat{\alpha}_1$, profits do not depend on α and if $\alpha \in (\frac{1}{2}, \hat{\alpha}_1)$ then profits decrease in α. Therefore, in this case, profits weakly decrease in α. For $\alpha < \frac{1}{2}$, from Claim 9, we know that $\hat{h}_3$ is decreasing in α. Therefore, there exists a $\hat{\alpha}_2$ such that profits decrease in α if $\alpha < \hat{\alpha}_2$ and do not depend on α otherwise. Therefore, in both cases, profits weakly decrease as α increase.

Consider also that, technically there is a possibility that for $\alpha < \hat{\alpha}_2$ Case 1 applies, for $\alpha \in (\hat{\alpha}_2, \frac{1}{2})$ Case 2 applies, and for $\alpha \in (\frac{1}{2}, \hat{\alpha}_1)$ Case 1 applies again. However, we can rule this out. To see this, first note that Π_2^* is independent on α. Therefore, if Case 2 applies then Π_2^* has a solution $p_2^* > \bar{v} - \beta h$. Furthermore, at $\alpha = \frac{1}{2} - \epsilon$, we have $\Pi_2^* > \Pi_1^*$ since Case 2 applies here by assumption. For Case 1 to apply for $\alpha = \frac{1}{2} + \epsilon$, we must have $\Pi_1^* > \Pi_2^*$. However, since Π_1 is decreasing with α and Π_2^* is constant, this can only happen if Π_1 jumps up at $\alpha = \frac{1}{2}$ and is strictly above Π_2^* at $\alpha + \frac{1}{2}$. However, this is not possible since the two profit functions are identical at $\alpha = \frac{1}{2}$.

Now consider the impact of α on prices. By the implicit function theorem, we have

$$\begin{aligned}\mathrm{sign}\left(\frac{\partial p_1^*}{\partial \alpha}\right) &= \mathrm{sign}\left(\frac{\partial^2 \Pi_1}{\partial p_1^* \partial \alpha}\right),\\ \frac{\partial^2 \Pi_1}{\partial p_1^* \partial \alpha} &= -2[F(\theta_2^*) - f(\theta_2^*)(p_1^*-c)] \\ &= -2\frac{\partial \Pi_o}{\partial p}\bigg|_{p=p_1^*} > 0, \qquad \text{(A.57)}\end{aligned}$$

where the inequality follows from Claim 10. For $\alpha > \frac{1}{2}$ since prices change continuously, this implies that prices weakly increase with α. However, for $\alpha \le \frac{1}{2}$, prices will increase at $\hat{\alpha}_3$ to p_2^*. Therefore, prices globally increase with α.

Consumers do not overconsume in Cases 2 and 3 and consumer health is independent with α. In Case 1, consumer health is $H = (1-\alpha)hF(\theta_2^*)$

$$\frac{\partial H}{\partial \alpha} = -hF(\theta_2^*) - (1-\alpha)hf(\theta_2^*)\frac{\partial p_1^*}{\partial \alpha} < 0, \qquad \text{(A.58)}$$

as $\partial p_1^*/\partial \alpha > 0$ as shown above. For $\alpha > \frac{1}{2}$, θ_2^* changes continuously and therefore H changes continuously. For $\alpha \le \frac{1}{2}$, θ_2^* increases discontinuously to 0 at $\hat{\alpha}_3$. Therefore, H globally decreases with α.

Now consider the impact of α on CS in the case of uniform distribution. In Case 1, the CS is

$$\begin{aligned}\mathrm{CS} &= \int_{\theta_2^*}^{\theta_1^*}(\bar{v}-\theta-p^*)f(\theta)\,d\theta \\ &\quad + (1-\alpha)\int_0^{\theta_2^*}(2v-2\theta-2p^*-h)f(\theta)\,d\theta \qquad \text{(A.59)}\end{aligned}$$

$$\frac{\partial \mathrm{CS}}{\partial \alpha} = \frac{\partial \mathrm{CS}(p^*)}{\partial \alpha} + \frac{\partial \mathrm{CS}(p^*)}{\partial p}\frac{\partial p^*}{\partial \alpha} > 0, \qquad \text{(A.60)}$$

because $\partial p^*/\partial \alpha > 0$ as shown above.

$$\frac{\partial \mathrm{CS}(p^*)}{\partial \alpha} = -\int_0^{\theta_2^*}(2\bar{v}-2p^*-2\theta-h)f(\theta)\,d\theta > 0, \qquad \text{(A.61)}$$

as $2\bar{v}-2p^*-2\theta-h < 2\bar{v}-2p^*-h < 0$ by the assumption that $\bar{v} < \theta_3^* = p + h/2$,

$$\begin{aligned}\frac{\partial \mathrm{CS}(p^*)}{\partial p} &= (\bar{v}-\theta_1^*-p^*)\frac{\partial \theta_1^*}{\partial p} - (\bar{v}-\theta_2^*-p^*)\frac{\partial \theta_2^*}{\partial p} - \theta_1^* + \theta_2^* \\ &\quad + (1-\alpha)\left[(2\bar{v}-2p^*-2\theta_2^*-h)\frac{\partial \theta_2^*}{\partial p} - 2\theta_2^*\right] \\ &= (1-\alpha)(h+2p^*-2\bar{v}) > 0, \qquad \text{(A.62)}\end{aligned}$$

where the inequality follows from the assumption that $\bar{v} < \theta_3^* = p + h/2$.

Finally, consider the impact of α on the incentives for the firm to produce healthier goods. Using the envelope theorem, we have

$$\frac{\partial \Pi^*}{\partial h} = (2\alpha-1)\beta f(\theta_2^*)(p^*-c). \qquad \text{(A.63)}$$

For the case when $\alpha \ge \frac{1}{2}$ we know the firm sets $\bar{h}$. So consider the case when $\alpha < \frac{1}{2}$. We examine how α impacts the right hand side (RHS) of (A.63). We have

$$\begin{aligned}\frac{d}{d\alpha}\left(\frac{\partial \Pi^*}{\partial h}\right) &= 2\beta f(\theta_2)(p^*-c) - \frac{\partial p^*}{\partial \alpha}\beta(1-2\alpha) \\ &\quad \cdot (f(\theta_2) - f'(\theta_2)(p^*-c)). \qquad \text{(A.64)}\end{aligned}$$

For uniform $f(\cdot)$ this reduces to

$$\frac{d}{d\alpha}\left(\frac{\partial \Pi^*}{\partial h}\right) = 2\beta(p^*-c) - \frac{\partial p^*}{\partial \alpha}\beta(1-2\alpha). \qquad \text{(A.65)}$$

We have $\partial p^*/\partial \alpha = -[\theta_2^* - (p^*-c)]/(2(1-\alpha)) > 0$. Therefore

$$\begin{aligned}\frac{d}{d\alpha}\left(\frac{\partial \Pi^*}{\partial h}\right) &= \beta\left[2(p^*-c) + \frac{1-2\alpha}{2(1-\alpha)}\cdot[\theta_2^*-(p^*-c)]\right] \\ &= \beta\left[(p^*-c)\cdot\frac{3-2\alpha}{2(1-\alpha)} + \frac{(1-2\alpha)\theta_2^*}{2(1-\alpha)}\right] > 0, \qquad \text{(A.66)}\end{aligned}$$

which completes the proof. □

Endnotes

[1] The rule was subsequently overturned by the courts (Draznin 2014).

[2] Alternatively, we could assume that even moderate consumption can lead to some harm δh where $\delta < 1$. Our results continue to hold in this alternate formulation. See Online Appendix B for details.

[3] For other approaches to modeling self-control, see, for example, Thaler and Shefrin (1981), Gul and Pesendorfer (2000), and Fudenberg and Levine (2006).

[4] Alternatively, h could affect the marginal cost and not the fixed cost. As long as the slope of the cost function is not too large, our main results would continue to hold in this alternate formulation. See Online Appendix E for details.

[5] When h is so high that consumers do not overconsume then there is a decrease in CS (see Figure 2). This is because the firm switches to the regime with no over-consumption and there is a discontinuous jump in prices, leading to a reduction in CS.

[6] Our results are consistent with the interpretation that unhealthier foods lead to a higher sense of guilt, if we interpret the parameter h as representing guilt.

[7] It is plausible that planners and impulsive buyers may have different levels of self-control and therefore β could be segment-specific. However, the relationship between self-control and planning behavior is unclear. On one hand, consumers who plan may have better self-control (i.e., a higher β) than consumers who shop without preplanning. On the other hand, consumers who have lower self-control may be more concerned about correcting their self-control failures by planning ahead. Low self-control consumers may also receive more training to help them plan shopping. Consequently, the relationship between self-control and planning is ambiguous. Therefore, we treat β as homogenous across planners and impulsive buyers. This assumption is also consistent with the alternate interpretation of α in which a consumer can be a planner with probability α. In Section 4.2, we analyze the case when consumers have heterogeneous self-control abilities.

[8] We normalize shopping costs to zero. Our result holds qualitatively if shopping is costly.

[9] If preplanning entails a small cognitive cost, then consumers who rationally overconsume would be better off as part of the impulsive segment. Because our interest is in cases where preplanning has some significance we restrict ourselves to this case.

[10] Note, however, that if we interpret α as the proportion of time that consumers plan, then over-consumption is an issue for all consumers.

[11] The condition on α ensures that there is some over-consumption.

[12] See Online Appendix A for the proof.

[13] However, in this case when $\alpha > \frac{1}{2}$ no consumer overconsumes and the equilibrium outcomes are independent of h. We can however establish that the basic forces in the base model continue to hold even when $\alpha < \frac{1}{2}$. We also considered a model with vertical and horizontal differentiation in which v is also distributed over the range of $(0, 1)$. We restrict the analysis so that for every θ at least some consumers overconsume. With this assumption, we can show that with preplanning profits can increase in h as in the base model and all of the main results survive (see Online Appendix D).

[14] Alternatively, this analysis can represent the case when consumers have heterogeneous self-control abilities.

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