Management Science

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

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To cite this article:
Sanjay Jain, Haipeng (Allan) Chen (2022) Sunk Cost Bias and Time Inconsistency: A Strategic Analysis of Pricing Decisions. Management Science

Published online in Articles in Advance 05 Jul 2022

. https://doi.org/10.1287/mnsc.2022.4479

http://pubsonline.informs.org/journal/mnsc

MANAGEMENT SCIENCE
Articles in Advance, pp. 1–18
ISSN 0025-1909 (print), ISSN 1526-5501 (online)

Sunk Cost Bias and Time Inconsistency: A Strategic Analysis of Pricing Decisions

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Received: February 18, 2021
Revised: August 27, 2021; December 28, 2021
Accepted: January 10, 2022
Published Online in Articles in Advance: July 5, 2022

https://doi.org/10.1287/mnsc.2022.4479

Abstract. It is generally acknowledged that sunk cost bias leads to suboptimal decisions, such as escalation of commitment. Some researchers, however, suggest that sunk cost bias can be beneficial when consumers have self-control problems. In this paper we explore the case when consumers with sunk cost bias have time-inconsistent preferences and, therefore, suffer from self-control problems. We experimentally demonstrate that sunk costs can make subjects better off by inducing higher effort. We then develop an analytical model to explore the implications of sunk cost bias for firm's pricing strategy. We find that, in the presence of sunk cost bias, higher prices can lead to higher experienced quality. We show that sunk cost bias can sometimes improve firm's profits, lead to lower prices, and increase welfare. Our results suggest that, when consumers use a product for multiple periods, pricing policies such as 0% financing, which are often viewed as exploitative, can instead lead to lower total prices, higher profits, and higher welfare.

History: Accepted by Matthew Shum, marketing.
Supplemental Material: The online appendix and data are available at https://doi.org/10.1287/mnsc.2022.4479.

Keywords: sunk cost bias • time-inconsistent preferences • behavioral economics • game theory • pricing

1. Introduction

Sunk costs are generally accepted to lead to suboptimal decisions and bad outcomes for consumers (Thaler 1980, 1985). This is because decision makers invest additional effort or money because of their earlier investment even though ex post the investments may not be optimal. There is a large literature on the negative impact of sunk cost bias, such as escalation of commitment (e.g., Staw 1976, Whyte 1993). Kahneman (2011, p. 385) concludes that "sunk-cost fallacy keeps people for too long in poor jobs, unhappy marriages, and unpromising research projects." Some researchers, however, suggest that sunk cost bias may make decision makers better off because it can help people overcome temptation (e.g., Nozick 1994, Walton 2002). Nozick (1994) argues that a consumer could buy several tickets to concerts in order to induce the consumer to attend more concerts. If the tickets were not bought in advance, then the consumer might find the effort to go to the event not worthwhile. Similarly, Walton (2002) discusses the example of a consumer who buys an expensive treadmill so that the consumer will be committed to exercising. These arguments suggest that sunk cost bias may not always be harmful because it can be used to correct for self-control problems.

Self-control issues and sunk cost bias can coexist for several product categories. For example, poor self-control is associated with lower rates of exercise, insufficient savings, overconsumption of vice goods, and low usage of feature-rich products (see, for example, Laibson 1997; DellaVigna and Malmendier 2004; Jain 2012, 2019). A unique feature of sunk cost bias relative to other biases studied in the literature is that sunk cost bias can be influenced by firm's pricing decisions. For example, sunk cost bias is larger when a consumer pays a higher price for an exercise machine. This suggests that, when deciding prices for product categories such as exercise machines, gym memberships, self-improvement programs (such as weight loss programs and education courses), and products that require learning, firms should take into account the effect of their prices on sunk cost bias and its impact on the consumer's future actions. Whereas there is a large literature that studies the negative

impact of sunk cost bias on decision making, the idea that sunk cost bias can be beneficial in the presence of self-control issues and it could have strategic implications for a firm's pricing decisions is relatively unexplored in previous literature (for an exception, see Xing et al. 2019).

Because the magnitude of sunk cost bias is affected by a firm's pricing decisions, firms can influence the realized value from their product by changing prices. If consumer usage increases because of sunk cost bias, intuitively, firms should be able to increase prices as the bias increases. However, it is also possible that higher sunk cost bias could induce firms to reduce prices in order to increase market demand. Thus, it is not a priori obvious how sunk cost bias affects pricing. Intuition suggests that, if sunk cost bias can alleviate problems associated with poor self-control, then such a bias can be welfare-improving. However, this intuition does not incorporate strategic pricing, and without a formal analysis, it is difficult to see how sunk cost bias affects welfare and firm profits. Furthermore, whereas sunk cost bias can alleviate some of the issues of self-control, it is also possible that consumers could overcorrect for such biases when sunk cost bias is large. For example, consumers can over-save, overexercise, or use products when the costs do not justify usage. It is not clear how firms should optimally price in such situations and how this affects profits and welfare. Examining these issues can enrich our understanding of the impact of sunk cost bias on decision making and is useful from both managerial and public policy perspectives. From a managerial perspective, the analysis can inform firms about optimal pricing and product design decisions. From a public policy perspective, such an analysis can help policy makers assess whether educating consumers about their biases is always beneficial or could lead to reduced welfare. The purpose of this paper is to develop a formal analytical model to study these issues.

Before developing our analytical model, we test the intuition that higher sunk cost can indeed lead to higher effort and make subjects better off. We conducted an incentivized experiment in which subjects were asked to identify word patterns in several paragraphs. Subjects were paid on the basis of the number of correct answers they identified. There was a delay between the time at which subjects exerted the effort and when they were paid. In order to participate, subjects needed to pay an up-front fee, which varied across groups. Our experimental results show that subjects who paid higher up-front fees exerted more effort, were more accurate, made a higher net payoff (even after accounting for the higher up-front fees), and were happier with the task compared with subjects who paid a lower fee. This result is consistent with the idea that sunk costs can be beneficial by inducing more effort and leading to higher payoffs.

Incorporating this experimental result into our analytical model, we consider a situation in which consumers need to invest effort in order to enjoy delayed benefits from a product or service. In our framework, the cost of effort can be low or high. When the costs are low, some consumers should invest effort, whereas for high costs, it is not optimal to exert effort. Consumers suffer from self-control problems so that some do not invest effort even when it is optimal to do so from a long-run perspective. Thus, the model incorporates two types of biases: self-control bias, which we model using time-inconsistent preferences, and sunk cost bias. The model also allows for both underinvestment and overinvestment. In this framework, we consider optimal pricing by firms and investigate how sunk cost bias affects prices, profits, and welfare.

Our analysis leads to several interesting results. We first show that, in the presence of self-control problems, sunk cost bias can lead to increased experienced quality. Prior research assumes that quality is inherent in the product and price can be a mechanism to signal quality and extract value (see, for example, Milgrom and Roberts 1986). Some researchers, however, argue that prices can increase experienced quality through psychological means, such as the placebo effect (Shiv et al. 2005). We show that, under some conditions, higher prices can lead to higher experienced quality even in the absence of placebo effects. The intuition is that, in the presence of sunk cost bias, higher prices can serve as a commitment device that ensures product usage, thereby increasing experienced quality. This implies that, for some product categories, firms can increase customer satisfaction by maintaining high prices.

Our results show that, for small values of sunk cost bias, the demand curve can be upward-sloping over some price range. Thus, we provide a reason why, in some contexts, consumers may have a minimum price below which they do not purchase a product. This result cautions managers that charging very low prices for product categories that involve self-control issues may lead to reduced demand. Our analysis shows that optimal prices decrease as sunk cost bias increases, and for some, parameter values are invariant to changes in marginal costs. We find that, for low values of sunk cost bias, an increase in this bias leads to improved consumer surplus, social welfare, and profits. Thus, sunk cost bias, whereas often viewed as hurting consumers, can be a win–win for all. However, this result can get reversed for large values of sunk cost in which overinvestment is an issue. We also analyze a situation in which consumers use the product for multiple periods. In such situations, we find that use of payment plans, such as 0% financing, can lead to lower total prices, improved welfare, and

higher profits. This is in contrast to other research that shows such plans are often exploitative and lead to higher total prices (Heidhues and Kőszegi 2010). From a managerial perspective, this result identifies a new role for such payment plans. We also analyze the case when there is competition. We find that sunk cost bias can lead to increased price competition and lower prices.

The rest of the paper is organized as follows. In Section 2, we discuss the relevant prior literature. In Section 3, we discuss the results of an experiment that validates the basic assumptions of the model. Section 4 presents the base model. We consider several extensions of the base model in Section 5 and conclude the paper in Section 6.

2. Related Literature

The paper is related to the large literature that shows that sunk costs affect decision making. Staw (1976) finds that sunk costs can lead to escalation of commitment (see also Whyte 1993). Thaler (1980) uses prospect theory to argue that a family is more likely to drive to a game through a snowstorm when they have paid for the game as opposed to when they receive the tickets for free. Similarly, Thaler (1999) suggests that an increase in the price paid for shoes may increase usage even when the shoes are uncomfortable. Arkes and Blumer (1985) show that subjects who paid for a season ticket attended more plays. They also show that a consumer who has paid $100 and $50 for two ski trips but can only go to one goes to the ski trip that cost $100 even when the consumer anticipates greater enjoyment from the $50 ski trip. Ülkü et al. (2020) find that consumers who spend more time waiting for a service purchase more to justify their time investment. Gourville and Soman (1998) measure the attendance at basketball games and find that attendance is highest for the games that are temporally closer to the payment. Ho et al. (2018) study how sunk costs can impact usage of durable goods and find that consumers with higher sunk costs when purchasing a car drive more. In most of this literature, sunk costs lead to suboptimal decisions. In contrast to this research, which typically focuses on the negative impact of sunk cost bias, we study a scenario in which sunk costs can lead to either negative or positive impact. In particular, we model consumers with self-control problems and sunk cost bias. We also incorporate firm's pricing decisions in response to sunk cost bias and show how pricing, profits, and welfare are impacted by such biases.

Some researchers try to rationalize sunk costs bias. Baliga and Ely (2011) consider the case in which decision makers may forget the reason why they invested in a project. They show that, in such cases, sunk costs can provide useful information. Hong et al. (2019) show that, when consumers are present-biased and have imperfect memory of their own abilities, then past investments can be useful as a signal of their ability or as a means to coordinate their actions across multiple periods. In contrast to this approach, we assume that both present-biased preferences and sunk cost bias exist and explore the implications for firm's pricing decisions and welfare.

Most prior research focuses on the impact of sunk costs on the decision makers but not on firms. Dick and Lord (1998) find that paying membership fees can lead to a more positive evaluation of the store and such attitudes can persist. This suggests that firms can benefit from using such membership fees because of sunk cost bias. The work that is closest to ours and models both sunk costs and time inconsistency is Xing et al. (2019) (see also Xing 2015). They first empirically show that consumers anticipate sunk costs. The paper then formally incorporates both time inconsistency and sunk costs in the modeling framework of DellaVigna and Malmendier (2004). The paper shows that sunk costs can improve utility for time-inconsistent consumers but can make time-consistent consumers worse off because of overconsumption. Xing et al. (2019) investigate how sunk costs affect optimal two-part pricing and find that higher sunk cost effects lead to lower fixed fees and higher per-visit fees. The paper shows that sunk cost and present bias do not affect profits and welfare. Xing et al. (2019) also find that, when undifferentiated firms compete, they make zero profits. Unlike Xing et al. (2019), we model heterogenous consumers, which allows us to examine different issues, such as how demand changes with price. We show that the demand curve can be upward-sloping, and prices can be invariant to costs for some parameter ranges. We also show how sunk cost bias and present-biased preferences change the nature of competition and affect firm's profits and welfare. Thus, our results show that profits and welfare depend on both present and sunk cost bias. We also show that undifferentiated firms can make positive profits and also examine the case when firms are differentiated.

The paper is also related to the large literature that models self-control problems using time-inconsistent preferences (e.g., Laibson 1997, O'Donoghue and Rabin 1999, DellaVigna and Malmendier 2004). Time inconsistency is used to study procrastination (see, for example, O'Donoghue and Rabin 1999, 2001), addiction (Gruber and Köszegi 2001, Machado and Sinha 2007), investment behavior (Laibson 1997), pricing (e.g., Schaefer et al. 2018), and product design (e.g., Jain and Li 2018). We model a situation in which consumers suffer from both self-control problems and sunk cost and show how sunk cost can alleviate or exacerbate self-control problems.

Another stream of research that is related to this paper considers situations in which the consumer exerts effort after purchase (see, for example, Lutz 1989, Albert Ma and Riordan 2002, Iyer and Singh 2018). Our focus is much different from this research, which studies underinvestment as a result of consumer moral hazard issues, whereas we focus on underinvestment or overinvestment because of the presence of self-control and sunk cost bias.

The paper is related to research that tries to incorporate multiple biases to derive new insights. For example, Bénabou and Tirole (2004) incorporate self-control problems and imperfect memory to show the emergence of internal commitments and personal rules. The paper is more generally related to the growing body of marketing literature that examines the strategic implications of consumer biases, such as context-dependent preference (Ho and Zhang 2008, Orhun 2009, Chen and Turut 2013, Amaldoss and He 2018), inequity aversion (Cui et al. 2007, Guo 2015), limited memory (Chen et al. 2010), and social effects (Amaldoss and Jain 2005, Lim 2010).

3. Experiment

Prior empirical research shows the tendency for subjects to overexert because of sunk cost bias. However, this research does not explore the possibility that increased effort could actually be beneficial in contexts in which payment is delayed. Furthermore, subjects in past research are usually not incentivized (see, for example, Staw 1976, Arkes and Blumer 1985). We want to see whether sunk cost bias can increase subjects' effort and welfare in an incentivized environment. To test this, we manipulate the price that subjects pay for a task and measure how hard they work, how much monetary reward they receive, and how happy they are with the task. We expect that, when subjects pay a higher price to engage in an activity, they exert more effort, receive a higher payoff, and are happier than when they pay a lower price. We then use this result to develop strategic implications of sunk cost bias on a firm's pricing decisions.

3.1. Procedure

Ninety-two business students at a Chinese college participated in this study. The average age of the subjects was 20, and 67% of the subjects were female. The subjects were in three sessions of the same course and participated in the study at different times of the same day. The subjects were physically distanced and verbal instructions and monitoring by the administrators prevented subjects from talking or looking at others' responses. When the study began, subjects were informed that they had an opportunity to participate in a task that could increase their concentration ability, and furthermore, they would get paid for their performance on the task. However, in order to participate, subjects were required to pay an up-front fee. The task involved identifying a sequence of letters of a particular pattern. The subjects were given an example of the task and were told that they would earn 0.35 yuan (about \$0.05) for each correct answer. Subjects were then given a piece of paper with a participation price and barcodes printed on the top of the page for payment. The price was either one or three yuan RMB (about \$0.15 and \$0.45, respectively).

If subjects decided to participate, they were asked to pay using their phones by scanning a barcode. Three students opted out at this point (with two in one condition and one in the other condition). The attrition rate was not different between the two conditions ($z = .59, p = .55$), leaving 44 subjects in the one-yuan condition and 45 in the three-yuan condition. After showing their payment on their phones to the study administrators, subjects were then given a unique ID. They were given another barcode to scan, which took them to an online survey (hosted by wjx.cn, an online portal similar to Qualtrics). The survey started with a cover page that, among other things, reminded subjects of the payoff for each correct answer (0.35 yuan or about \$0.05). The survey instructions informed the subjects that they could stop at any point in time independently of others. Underneath the instructions, subjects provided their participation ID again and an Alipay account number to receive their earnings.

After the cover page, subjects were shown the actual tasks, which consisted of paragraphs on separate pages. Before each paragraph, subjects were given instructions as to the specific letter strings that they should identify. For example, subjects could be asked to identify a pattern, such as the letter "e" followed by any letter and a vowel (see Online Appendix A for an example task). After being given an example, subjects were asked to write down the words containing such letter strings.

After completing the first task, subjects were asked to indicate whether they wanted to continue. If subjects did not want to continue, they were taken to the end of the survey. If subjects indicated that they wanted to continue, they were shown another paragraph with a different letter string to identify. There were a total of nine different paragraphs with different strings to identify and different numbers of correct answers for each. Subjects were not told the total number of paragraphs in the survey. The survey automatically recorded the amount of time that the subjects took to complete the task (without subjects being aware of it). The survey also asked subjects' age and gender. Subject's responses were graded by graduate students who were blind to the predictions and

experimental conditions, and subjects were paid the next day. Thus, there was a delay between the time at which the subjects completed the task and when they were subsequently paid. We expected that subjects who paid a higher price would work harder and receive a higher payoff than those who paid a lower price. Later, we took additional measures to provide preliminary evidence for (1) the roles played by sunk cost and present bias and (2) how subjects felt about the focal task (see Section 3.3).

3.2. Results

To test our predictions, we measured subjects' effort using the time they spent on the task, the number of paragraphs they attempted, and the number of words they wrote down on the answer sheets. We measured their performance using their accuracy in identifying the letter strings. We analyzed subjects' effort and performance as a function of the price they paid to participate. To control for possible differences across the three sessions of the course, we included the session number as an additional variable. Specifically, we subjected the effort and performance measures to a 2 (price: low (one yuan) versus high (three yuan)) × 3 (session) ANOVA. In all the analyses, the main effect of course session was significant ($p < 0.05$), indicating that subjects in the first session spent less effort and performed worse than those in the other two sessions (the latter two sessions did not differ from each other, $p > 0.10$). The interaction effect between price and session was not significant ($p > 0.20$ or worse), and the results in different sessions were qualitatively similar on all dependent measures.

Table 1 presents the key results. First, we find that, consistent with our hypothesis, the main effect of price was significant. Specifically, a 2 × 3 ANOVA on time spent revealed a significant main effect of price, such that subjects in the high price condition spent more time than those in the low price condition ($M_{1yuan} = 54.30$ versus $M_{3yuan} = 61.17$ minutes; $F(1,83) = 6.41$, $p < .05$). A similar analysis revealed that those who paid a higher price attempted more paragraphs ($M_{1yuan} = 7.05$ versus $M_{3yuan} = 7.56; F(1,83) = 4.34$, $p < .05$) and wrote down more words on the answer sheets ($M_{1yuan} = 89.93$ versus $M_{3yuan} = 107.91$; $F(1,83) = 8.19$, $p < .01$). Therefore, as predicted, we find that subjects who paid a higher price exerted more effort.

In addition, a 2 × 3 ANOVA revealed a significant main effect on the number of accurate answers ($M_{1yuan} = 63.27$ versus $M_{3yuan} = 78.24; F(1,83) = 8.33, p < .01$). Whereas this translates into a higher overall accuracy rate (42.46% versus 52.51%, $p < 0.01$), the data also shows that subjects who paid a higher price had a higher accuracy rate among the paragraphs they attempted ($M_{1yuan} = 51.34\%$ versus $M_{3yuan} = 61.97\%$; $F(1,83) = 5.59, p < .05$). As a result of their heightened effort (i.e., trying longer and attempting more paragraphs) as well as their better accuracy (i.e., getting disproportionately more correct answers), overall, subjects who paid a higher price were financially better off despite paying more to participate in the task (i.e., number of correct answers multiplied by 0.35 yuan minus the price they paid; $M_{1yuan} = 21.14$ yuan or about \$3.25 versus $M_{3yuan} = 24.39$ yuan or \$3.75; $F(1,83) = 4.15, p < .05$).

3.3. Additional Measures and Analysis

To provide preliminary evidence for the roles of sunk costs and present bias in the effect we documented and for our claim that subjects who paid a higher price were better off, we obtained additional measures on separate occasions, matching them using subjects' Alipay account numbers.

3.3.1. Sunk Costs. As a proxy of sunk costs, we asked subjects the following question on a five-point scale (one = strongly disagree; five = strongly agree): "Given how much I paid to participate in the task, I would have regretted it if I hadn't taken full advantage of the task." This captures the idea that experiencing a larger sunk cost should be reflected in feeling more regret in not taking advantage of the task to earn as much money as possible. An ANOVA on regret reveals a significant effect of price ($F(1,86) = 4.00, p < .05$) with regret of not taking full advantage of the task being higher in the high price condition ($M = 3.78, SD = .97$) than in the low price condition ($M = 3.36, SD = 1.04$). A mediation analysis (PROCESS, model 4, Hayes 2017) with price as an independent variable, payoff as the dependent variable, and regret as the mediator, reveals a positive effect of price on regret ($a = .21, p = .048$) and a positive effect of regret on payoff ($b = 2.04, p = .068$). The indirect effect is marginally significant ($a \times b = .44$, $90\%\, CI = (.01, 1.05)$). The direct effect became insignificant

Table 1. Experimental Results

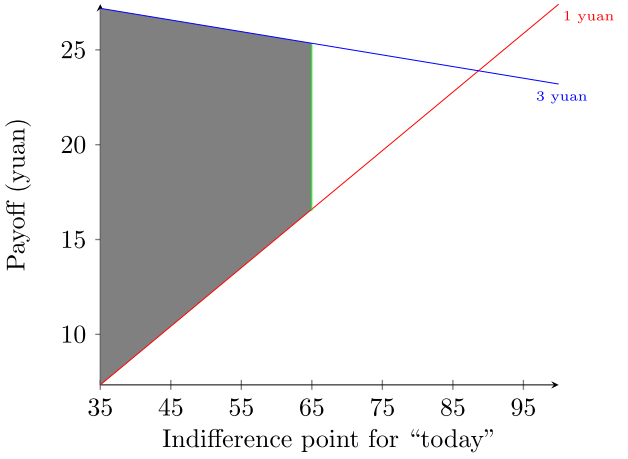
Price paid	Time spent	Number of paragraphs attempted	Number of words written	Number correct answers	Accuracy, %	Net payoff
One yuan	54.30	7.05	89.93	63.27	51.34	21.14 yuan
	(15.84)	(2.21)	(42.97)	(35.62)	(23.34)	(12.47)
Three yuan	61.17	7.56	107.91	78.24	61.97	24.39 yuan
	(17.08)	(1.62)	(52.60)	(27.72)	(20.94)	(9.70)

($c = 1.58, p = .16$). With regret as a rough proxy for sunk cost, these results provide some preliminary evidence for the expected role sunk costs may have played in driving the focal price effect on payoff.

3.3.2. Present Bias. To demonstrate the role of present bias, we measured indifference points for "today" and "tomorrow" for 100 yuan in a week in an incentive-compatible manner (following Benhabib et al. 2010). Specifically, subjects were told that, if they were the winner of a random drawing, they would receive 100 yuan in a week. They were then asked to indicate the amount that would make them indifferent between receiving it that day (today) and receiving 100 yuan in a week. To make their responses incentive-compatible, subjects were told that a random number would be drawn from 1 to 100, and if the number were bigger than their indifference point, they would receive the amount they named on that day; otherwise, they would receive 100 yuan in a week. They were then asked about their indifference point for the following day (tomorrow) in a similar, incentive-compatible manner. In our analysis, we used subjects' indifference point for today to capture the present bias. Specifically, for a given indifference point for tomorrow (for which we controlled in our analysis), a lower indifference point for today corresponds to a stronger present bias. A moderation analysis with price as the independent variable, payoff as the dependent variable, indifference point for today as the moderator, and indifference point for tomorrow as a control variable (PROCESS, model 1, Hayes 2017) reveals a significant interaction between price and the indifference point for today on payoff ($b = -.19,\ p = .04$). The main effect of price is positive and significant ($b = 16.41, p = .03$); so is the main effect of the indifference price for today ($b = .49,\ p = .03$). The effect of the indifference point for tomorrow is not significant ($b = .11, p = .33$).

A floodlight analysis (see Figure 1) for the significant interaction reveals that a high price increased payoff more than a low price but only among those whose indifference point for today was low (< 66 yuan) and not when it was high (> 66 yuan). These results are robust when we remove the control variable from the analysis ($b = -.20, p = .03$ for the interaction; the cutoff point for the significant region is < 75 yuan). Note that these measures were taken on a separate occasion, thus minimizing possible demand effects. If these measures were taken on the same occasion as the focal task, subjects who worked hard and made more money might have wanted to appear to be less present biased to be self-consistent. The results, thus, provide some preliminary evidence for the expected role of present bias in moderating the focal price effect on payoff.

Figure 1. (Color online) Payoff as a Function of Price and Quasi-Hyperbolic Discounting



3.3.3. Are Subjects Who Paid a Higher Price Better Off? Our analysis in Section 3.2 shows that subjects who paid a higher price made more money (even after accounting for the higher price they paid). However, this does not take into account the effort subjects exerted, and therefore, subjects may not be better off because they may also have spent more effort. To examine this possibility, we reminded subjects of the focal task ("Remember the task of identifying sequences of letters you participated in last time?") and asked them how satisfied and happy they were with the task.

The responses for the two questions were positively correlated (correlation = 0.79, $p = 0.000$). After averaging them, a two-way ANOVA revealed a marginally significant main effect of price with those in the high price condition being more satisfied and happier than those in the low price condition ($M_{3yuan} = 5.77,\ M_{1yuan} = 5.35, F(1,74) = 3.67, p = .059$).[1] The main effect of class session was marginally significant ($F(2,74) = 2.39$, $p = .099$) with those in the first session being less satisfied and less happy than those in the third session ($5.28 < 5.82$, $p = 0.087$; $p > 0.10$ for the other pairwise comparisons among sessions). The interaction between price and class session was not significant ($F(2,74) = 1.45, p = .24$). The results are qualitatively similar when satisfaction and happiness are analyzed separately with a marginally significant effect of price for both measures ($p = 0.066$ and 0.079; $p = 0.097$ and 0.151 for the main effect of session; $p = 0.222$ and 0.334 for the interaction). With the caveat that the measures were taken on a separate occasion after the conclusion of the focal task (and, thus, do not capture subjects' real-time feelings when doing the task), these results provide preliminary evidence that subjects who paid a higher price may be better off.

Overall, the results of the experiments are consistent with the hypothesis that a higher initial price can lead to more effort and can make subjects better off even after accounting for the higher price that they pay. We now use this result to formally examine the pricing implications using an analytical framework.

4. Model

Consider a monopolist who sells a product that provides value v. We assume that v varies across consumers according a to a distribution $F(\cdot)$ with support $(0, 1)$. For the product to provide value, the consumer needs to exert some effort. This effort is temporally separated from the benefit received. For example, for many products, consumers need to learn to use the product before usage. Some products require assembly or setup before the consumer can use the product. For example, consumers need to assemble furniture, program robotic vacuums, etc. For products, such as exercise machines and gym memberships, the effort is immediate, but eventual benefits are not immediately realized (DellaVigna and Malmendier 2004). Similarly, a consumer who buys tickets for a game needs to invest effort in order to attend at a future date. Note that it is possible that the consumer receives some immediate benefits after exerting effort. For example, a visit to the gym can lead to better mood or chance to socialize. Similarly, after learning how to use a software, the consumer might be able to put it to immediate use. The immediate benefit can be accommodated in our model if we assume that the costs are net of such benefits. We, however, do require that the key benefits are received with delay. For example, health benefits of going to the gym are only enjoyed in the future.

We want to model the idea that sunk costs can affect the tendency for consumers to underinvest because of self-control problems. At the same time, we want to be able to capture the idea that sunk costs can lead to overinvestments. Finally, we also want to model the fact that costs may differ across consumers. In order to model this in the simplest possible and tractable way, we assume that the cost distribution is discrete. The cost of effort required could be individual- or situation-specific. For example, a consumer who buys a new software may not be aware whether the consumer will find the product to be difficult or easy to use. Alternatively, a consumer who buys tickets for a game may find it convenient to attend, or the times may conflict with more important priorities. We assume that consumers do not a priori know the exact costs that they will experience, but know the distribution of the costs. In particular, we assume that, with probability α, the effort required is $1 > \kappa > 0$, whereas with probability $(1-\alpha)$ the cost is one. Thus, for all consumers with $v > \kappa$, it is worthwhile to exert effort, but if the costs are high, then it is not optimal for any consumer to exert effort. Therefore, a consumer with $v > \kappa$ who does not exert effort underinvests. Conversely, if the consumer exerts effort when the costs are high, then the consumer is overinvesting. Our formulation allows for both overinvestment and underinvestment.

In order to represent the possibility that self-control problems can lead to underinvestment, we assume that consumers use quasi-hyperbolic discounting. This approach is used by several researchers (see, for example, Laibson 1997, Gruber and Köszegi 2001, Jain 2019). In particular, we assume that the consumer uses the following function:

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

Here, t is time, $0 \le \beta \le 1$ is the quasi-hyperbolic discount parameter, and δ is the exponential discount parameter. Note that, in this formulation, the consumer's discounting depends on the time at which the consumer makes the decision, and the preferences are time-inconsistent. For example, a consumer at time 0 finds it worthwhile to exert effort when costs are low if $\beta\delta(\delta v - \kappa) > 0$. However, at time 1, this consumer prefers to exert effort only if $\delta\beta v - \kappa > 0$. This time-inconsistency cannot happen if $\beta = 1$ and consumers discount using the usual exponential discount factor. In such a case, the consumer has time-consistent preferences and has no self-control problems. However, as β decreases, the consumer's self-control problem increases and preferences are time-inconsistent. We set $\delta = 1$ as is common in the prior literature (see, for example, O'Donoghue and Rabin 1999).

4.1. Demand

We first derive the demand function in the case of a monopolist. Later, in Section 5.3, we examine the competitive case. In period 0, the monopolist firm offers a contract to sell a durable good at price p.[2] If the consumer signs the contract, the consumer pays p in period 1. Note that we assume the consumer's decision to buy and the payment are temporally separated. This is similar to the assumption in DellaVigna and Malmendier (2004). Jain (2019) argues that this is reasonable because, as long as the firm has an exponential discount close to one, it is optimal for the firm to offer to delay payment by one period. Alternatively, the model can be viewed as assuming that the payment is made in period 0 but there is no time-discounting of prices and only effort is time-discounted. This is consistent with the empirical

findings of Augenblick et. al. (2015). The assumption, however, is not critical, and the key results survive even when payment is made when the contract is signed (see Online Appendix C for details).

In period 2, the consumer observes the costs and decides whether to exert effort. If the consumer invested in period 2, then the consumer receives the benefits in period 3. The firm chooses p to maximize its profits. We start the analysis with the assumption that consumers are aware of their biases. We discuss the effect of relaxing this assumption later.

With these assumptions, first note that a present-biased consumer does not consume if the cost is one. This is because, in this case, $\beta - 1 < 0$.[3] Let us now discuss the case when the costs are low, that is, κ. A present-biased consumer uses the product in period 2 only when the costs are low and $\beta v - \kappa > 0$. This leads to underusage because the consumer should be willing to exert effort when $v - \kappa > 0$. Now, consider the case when the consumer experiences sunk cost bias when the consumer realizes that the consumer has not recovered the consumer's investment. This effect is proportional to the price that the consumer pays. Suppose the consumer pays p; then, we assume that, if the product is not used, the consumer experiences a sunk cost discomfort $-\lambda p$. Thus, the consumer uses the product by investing κ if $\beta v - \kappa + \lambda p \geq 0$. In other words, the consumer uses the product if $v \geq \frac{\kappa - \lambda p}{\beta} \equiv v_1$. We assume that at least some consumers are willing to invest effort when the cost is low even under present-biased preferences, that is, $\beta > \kappa$. This implies $v_1 < 1$.

Now, consider the case when the costs are high and equal to one. In this case, no consumer should be willing to invest effort. However, a consumer at v may still be willing to exert effort to close the mental account if $\beta v - 1 + \lambda p > 0$, that is, $v > \frac{1 - \lambda p}{\beta} \equiv v_2$. It is easy to see that $v_2 > v_1$. If $v_2 < 1$, then some consumers overconsume. This overconsumption is due to the presence of sunk cost bias. Thus, our formulation allows underinvestment because of self-control bias and overconsumption because of sunk cost bias. In order to make purchase decisions, a consumer needs to forecast the consumer's future actions. We assume that the consumer has rational expectations and knows the parameters β and λ. Later, in Section 5.1, we discuss the implications of relaxing this assumption.

A consumer who expects to use the product only under low costs buys as long as

$$U_l = \alpha(v - \kappa) - p > 0. \tag{2}$$

Thus, consumers with $v \in (v_1, v_2)$ purchase only if $v > \frac{p}{\alpha} + \kappa \equiv v_3$. Similarly, consumers who expect to always use the product buy if

$$U_h = v - \alpha\kappa - (1 - \alpha) - p > 0. \tag{3}$$

Therefore, consumers with $v \in (v_2, 1)$ purchase the product only if $v > p + \alpha\kappa + (1 - \alpha) \equiv v_4$. Thus, the demand is given by

$$\begin{aligned} \mathrm{D}(p) = {} & \max(0, F(v_2) - F(\max(v_1, v_3))) \\ & + \max(0, 1 - F(\max(v_2, v_4))). \end{aligned} \tag{4}$$

The first term is the demand from the segment that exerts effort only under low costs, and the second term is the demand from the consumers who always exert effort. The critical values v_1, v_2, v_3, and v_4 depend on price. The following proposition derives the demand function more explicitly.

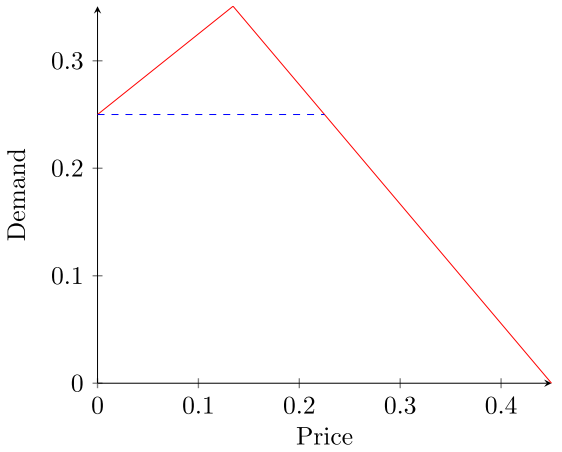
Proposition 1. *Suppose $\lambda < \frac{1-\beta}{\alpha(1-\kappa)}$; then, the demand is given by*

$$\mathrm{D}(p) = \begin{cases} 1 - F(v_1) & \text{if } p \leq \hat{p}_a \\ 1 - F(v_3) & \text{if } p \in (\hat{p}_a, (1-\kappa)\alpha), \\ 0 & \text{if } p \geq (1-\kappa)\alpha \end{cases} \tag{5}$$

where $\hat{p}_a = \frac{\kappa(1-\beta)\alpha}{\lambda\alpha + \beta}$. Demand increases in price for $p < \hat{p}_a$ and decreases otherwise. Furthermore, demand weakly increases in λ and β.

Proofs of all the propositions are in Online Appendix B. The proposition shows the demand for low values of sunk cost bias. Figure 2 depicts how the demand changes with price. The dashed line shows the demand when there is no sunk cost bias, that is, $\lambda = 0$. Note that v_2 is decreasing in price. Therefore, the demand curve is upward-sloping for $p < \hat{p}_a$. In order to understand this, note that sunk cost bias leads to more incentives to invest in effort after purchase. When $\lambda < \lambda_1$, then the bias is not large enough to induce overinvestment. However, sunk cost bias can correct for the underinvestment because of

Figure 2. (Color online) Demand When Sunk Cost Bias Is Small



self-control issues. In particular, absent sunk cost bias, only consumers with $v > \frac{\kappa}{\beta}$ invest, and therefore, sales are at most $1 - F(\frac{\kappa}{\beta})$. This can be seen in Figure 2 in which the dashed line is below the demand curve for $p < \hat{p}_a$. However, sunk cost bias increases the number of consumers who are willing to invest. Consumers purchase the product when either the investment constraint or the price constraint binds, that is, when $v \geq \max(v_2, v_3)$. For low prices, the investment constraint binds. However, as the prices increase, this constraint becomes more relaxed, and therefore, the demand increases. For large prices, the price constraint binds, and the demand curve is downward sloping. An immediate consequence of this result is that in the presence of present and sunk cost bias, there is a minimum price that the firm charges, that is, the firm does not charge a price less than $\hat{p}_a$.

It is interesting to note that an increase in price can lead to higher experienced benefit. In particular, a consumer who pays a higher price can experience more benefit from the product and can be more satisfied with the purchase. In other words, a higher priced product can lead to a higher effective quality. This is because, in the presence of sunk cost bias, higher prices can act as a commitment device to ensure product usage, which leads to higher experienced quality. Typically, in the literature, price and product quality are independent. Prior research assumes that quality is inherent in the product, and price can be a mechanism to signal quality and extract value (see, for example, Milgrom and Roberts 1986). Some researchers, however, argue that prices can increase experienced quality through psychological means, such as the placebo effect (Shiv et al. 2005). In our formulation, price can *lead* to higher experienced quality without placebo effects. In particular, in our formulation, the increased efficacy of higher prices on experienced quality is due to a conscious process and not a perceived relationship between price and quality. Rather, in our formulation, consumers understand that sunk cost effects lead to higher effort, which, in turn, leads to higher experienced quality. Thus, our results suggest that a consumer who buys a more expensive gym machine may, in fact, experience a higher benefit not because the machine's inherent quality is higher, but because the consumer exercises more. We also find that as the sunk cost bias increases or the present bias decreases (i.e., β increases), consumer demand increases. Thus, the result shows that the presence of one bias, that is, present bias, can be counteracted by the presence of another bias, that is, sunk cost bias, and can potentially improve welfare. This is consistent with the idea proposed by Nozick (1994). Now let us consider the case when sunk cost bias is large.

Proposition 2. *If $\lambda > \lambda_1$, then the demand function is*

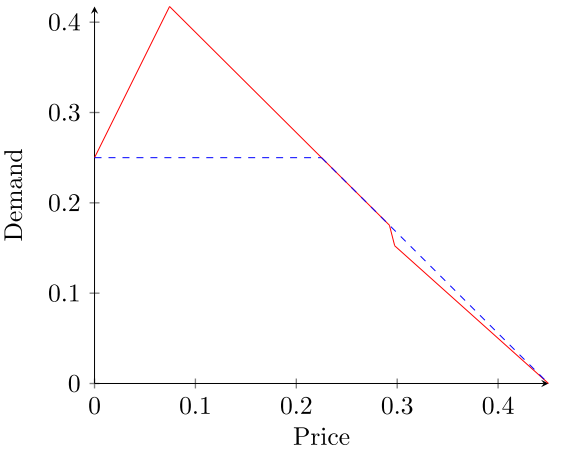
$$\mathrm{D}(p) = \begin{cases} 1 - F(v_1) & \text{if } p \leq \hat{p}_a \quad (6a) \\ 1 - F(v_3) & \text{if } p \in (\hat{p}_a, \hat{p}_b] \quad (6b) \\ F(v_2) - F(v_3) + 1 - F(v_4) & \text{if } p \in (\hat{p}_b, \hat{p}_c] \quad (6c) \\ 1 - F(v_4) & \text{if } p \in (\hat{p}_c, (1-\kappa)\alpha) \quad (6d) \\ 0 & \text{if } p \geq (1-\kappa)\alpha \quad (6e) \end{cases}$$

where $\hat{p}_b = \frac{1-\beta(\alpha\kappa+1-\alpha)}{(\lambda+\beta)}$ *and* $\hat{p}_c = \frac{\alpha(1-\kappa\beta)}{\lambda\alpha+\beta}$.

Figure 3 depicts the demand curve. The dashed curve shows the demand when sunk cost bias does not exist. The proposition reveals additional forces in play when the sunk cost bias is large enough. As before, demand first increases in prices and then start to decline. However, when prices are large enough, that is, when $p > \hat{p}_b$, some high-valuation consumers may find themselves overinvesting even when the costs are high. This is consistent with the example in Thaler (1980) in which a consumer who has paid for a basketball game attends even when there is a blizzard. The cost in this case does not justify going to the game, but sunk cost bias does. Similarly, consumers who pay for a gym may sometimes overexert themselves, and consumers who find a product to be too difficult to use might overinvest in usage costs even though it may not be economically worthwhile.

The analysis shows that, for large values of sunk cost bias, high-valuation consumers may have a lower expected valuation than the lower valuation consumers. As a result, there is a hole in the demand such that consumers with $v \in (v_2, v_4)$ do not purchase the product, whereas consumers with lower valuation, that is, with $v \in (v_3, v_2)$, purchase (see Equation (6c)). Consequently, demand can be lower with sunk cost bias relative to the demand when sunk cost bias does

Figure 3. (Color online) Demand When Sunk Cost Bias Is Large



not exist. This can be seen in Figure 3 by comparing the solid line with the dashed line. This nonmonotonicity of preferences is noted in the prior literature in the context of vice goods (Jain 2012). Vice goods are those in which the benefits are immediate, but the costs are in the future. This is not the situation we are studying because, in our context, costs are immediate and benefits are in the future. Finally, when prices are higher than $\hat{p}_c$, $v_3 > v_2$, the situation resembles the outcomes in a vice goods case in which only consumers who have sufficiently high valuation purchase despite overconsumption (see Equation (6e)).

Prior literature makes a distinction between investment goods for which present bias leads to underinvestment and leisure or vice goods for which overinvestment occurs (e.g., DellaVigna and Malmendier 2004). Investment goods are characterized by the situation that costs are immediate, but benefits are in the future. Conversely, benefits are immediate and costs are in the future for vice goods. Thus, overinvestment and underinvestment occur based on product characteristics, and typically, these cases are analyzed separately. Our formulation resembles the investment good scenario in that costs are immediate, whereas the benefits are in the future. Yet, for some consumers, the same product acts as a vice good, whereas for other consumers, their tendency to under-consume because of present bias is counteracted by sunk cost bias, and they only exert effort when it is optimal to do so. Furthermore, the same consumer could underinvest for low prices and overinvest for higher prices. In other words, firms can strategically control the level of investment by setting prices.

4.2. Firm Sets Optimal Prices

Now, we consider the case when the firm can set prices. We want to examine the impact of sunk cost bias on prices, profits, and welfare when consumers have time-inconsistent preferences. Because time-inconsistent preferences imply that preferences change over time, one needs to choose the preferences that are used in welfare analysis. We follow prior literature that argues the correct benchmark for welfare analysis is consumer's long-run preferences, that is, when $\beta = 1$ (see, for example, Gruber and Köszegi 2001, DellaVigna and Malmendier 2004). Note, however, that actual β still impacts welfare because it affects optimal prices and demand.

If the effort constraint is not binding, then the firm sets a price p_r that is defined by

$$p_r \equiv \arg\max_p (p - c)(1 - F(v_3)), \tag{7}$$

where c is the marginal cost. We assume that the profit function is strictly concave, which requires that $1 - F(p)$ is concave and ensures that there is a unique p_r. Furthermore, we assume that c is sufficiently small and, in particular, $c < \hat{p}_a$.

First, consider the case when λ is small. We have the following result.

Proposition 3. *If $\lambda < \lambda_1$ and $p_r < \frac{\kappa\alpha(1-\beta)}{\beta}$, then*

a. *There exists a λ^* such that the optimal prices are $\hat{p}_a$ for $\lambda \in (0, \lambda^*)$ and p_r for $\lambda > \lambda^*$, where $\hat{p}_a = \frac{\kappa(1-\beta)\alpha}{\lambda\alpha+\beta}$.*

b. *There exists a c^* such that optimal prices do not depend on c for $c \in (0, c^*)$.*

c. *Firm profits, consumer welfare, and social welfare are weakly increasing as sunk cost bias (λ) increases.*

The proposition shows that, for low values of λ, the optimal price is $\hat{p}_a$ (see Figure 4). The reason is that, in such a situation, the usage constraint binds, and the demand function is increasing in price as we see in Proposition 1. Interestingly, this implies that price does not depend on marginal costs for low values of costs. An implication of this is that prices may be rigid even when material or labor costs change as can be seen in Figure 5. There is other research that tries to explain price rigidity when the prices are insensitive to cost changes by appealing to menu costs (Levy et al. 1997), consumer inattention (Levy et al. 2011), and loss aversion (Heidhues and Kőszegi 2008). Our research provides another explanation for this phenomenon. The proposition also shows that sunk cost bias can be good for the firm, the consumers, and the overall society (see Figure 6). In other words, sunk cost bias can be a win–win for all the participants. This is in contrast to most prior literature, which argues that sunk cost bias is harmful at least to the consumer. In our context, sunk-cost bias alleviates a consumer's self-control problem, which increases consumption, thereby increasing profits and welfare.

It is interesting to note that the optimal price for small λ is $\hat{p}_a$, which is increasing in κ. In other words,

Figure 4. (Color online) Optimal Price When Sunk Cost Bias Is Small

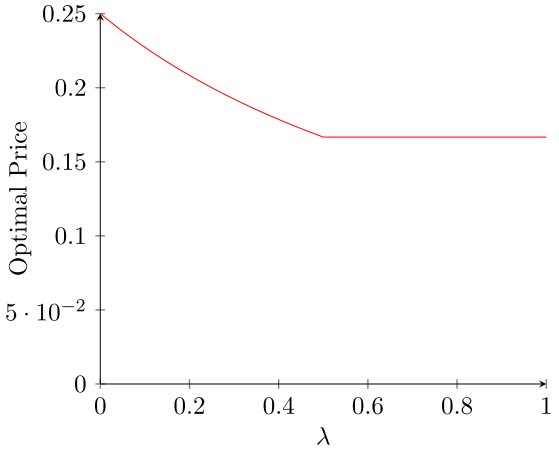
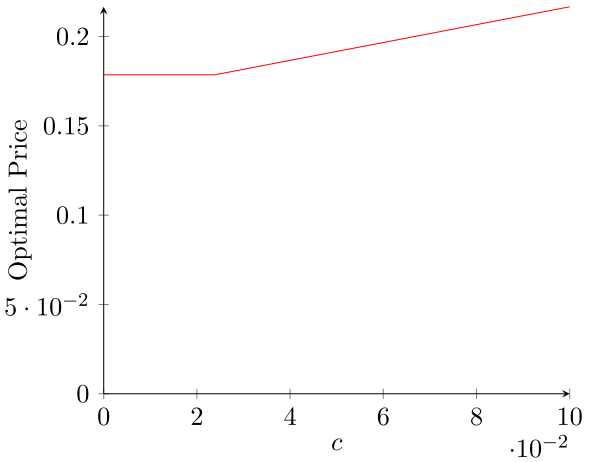
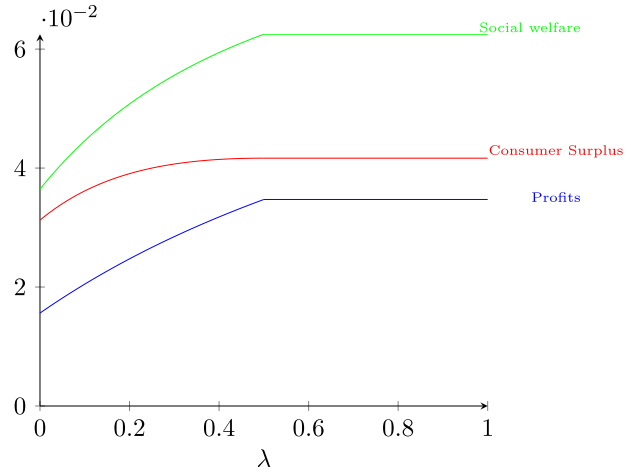


Figure 5. (Color online) Optimal Price Varies with c When Sunk Cost Bias Is Small



the firm is able to charge higher prices when it produces a product that is more difficult to use! This raises the possibility that, in such cases, the firm may benefit from increasing κ. Because a less easy-to-use product with the same functionality can be considered a lower quality product, this implies that sunk cost effects can lead to a lower quality product. To investigate this, consider the case when the firm can invest in reducing κ and a reduction of $0 < q < \kappa$ can be achieved by investing $\phi(q)$, where $\phi' > 0$ and $\phi'' > 0$, $\phi(0) = 0$ and $\phi'(0) < \infty$. For example, a firm can design the product such that usage is more intuitive or provide better usage instructions. This decreases the usage costs for the consumer. Let q^* denote the optimal investment in increasing ease of use. We have the following result.

Figure 6. (Color online) Profits and Welfare When Sunk Cost Bias Is Small



Proposition 4. *When $p^* = \hat{p}_a$, $q^* > 0$. However, the firm invests less in ease of use as sunk cost bias increases, that is, q^* decreases in λ.*

The first part of the proposition shows that the intuition that the firm may not want to invest in ease of use is not correct. To see this, note that the profit for the firm when it charges $\hat{p}_a$ is given by

$$\Pi = (\hat{p}_a - c)\left(1 - F\left(\frac{\hat{p}_a}{\alpha} + \kappa - q\right)\right) - \phi(q). \tag{8}$$

The price $\hat{p}_a$ decreases as the firm invests in improvement in ease of use, that is, q, but the second term, that is, the demand increases as q increases. It turns out that, for the case when $p^* = \hat{p}_a$, the demand effect dominates for small q, and therefore, $q^* > 0$ (see Online Appendix B for a proof). However, the sunk cost bias still impacts the level of q^*. In particular, an increase in λ leads to *lower* quality product. There are two reasons for it. First, when the effort constraint binds and the optimal price is $\hat{p}_a$, an increase in ease of use *reduces* the price that the firm can charge. This is because higher prices can be used as a commitment device, which leads to higher usage. If the product is more difficult to use and the effort constraint binds, the firm needs to increase price more in order to ensure usage. Therefore, when the effort constraint binds, the optimal price is increasing in the cost of usage. This reduces the incentives for the firm to invest in easy-to-use products. Note that this means that, in the presence of self-control and sunk cost bias, price and quality can be substitutes! Thus, the firm may prefer to have lower quality in order to enable it to charge higher prices. This is in contrast to most models in which higher quality enables the firm to charge higher prices. Another reason why the firm may invest in improving ease of use is that demand is less sensitive to an increase in q for higher values of sunk cost bias, that is, $\frac{\partial^2 D}{\partial q \partial \lambda} < 0$. This, again, reduces the incentive for the firm to invest in making easier-to-use products when sunk cost bias is larger.

Proposition 4 refers to the case in which the firm is investing in ease of use. However, the firm could instead invest in improving functionality. To model this, consider the case when the product valuation is qv, where $q > 0$, and the firm's cost for increasing is $\phi(q)$ as before. It turns out that, even in this case, if the optimal price is $\hat{p}_a$, then the firm invests less in improving functionality for higher values of sunk cost bias. In this case, $\hat{p}_a$ is independent of an increase in q, but the demand is still less sensitive to quality increase for higher levels of sunk cost bias (see Online Appendix B for a formal proof). Taken together, Propositions 3 and 4 show that, whereas sunk cost bias can lead to higher welfare in the short run, if we consider

long-term quality investments, then the results could differ.

Now, let us consider the case when $\lambda > \lambda_1$. In this case, for low prices, consumers face self-control problems and underconsumption is an issue. However, for larger prices, the consumer makes purchase decisions in light of overconsumption problems. In order to get sharper insights, we restrict our analysis to the case in which $F(\cdot)$ is uniform.

Proposition 5. *Suppose $\lambda > \lambda_1$ and $F(\cdot)$ is uniform; then,*

a. *If $\lambda \in (\lambda_1, \lambda_2)$, then $p^* = p_r$, where $\lambda_2 = \frac{2(1-\beta)+\alpha\beta(1-\kappa)-\beta c}{c+\alpha(1-\kappa)}$. Otherwise, $p^* \leq p_r$.*

b. *There exists a $\hat{\lambda} > \lambda_2$ such that, if $\lambda \in (\lambda_2, \hat{\lambda})$, then demand, consumer welfare, and social welfare increase in λ. Otherwise, demand and social welfare decrease in λ.*

c. *The firm's profits decrease in λ.*

To understand the optimal pricing by firm, first note that the optimal prices depend on p_r. If $p_r < \hat{p}_a$, then the firm again faces an increasing demand function for $p \in (0, \hat{p}_a)$, and therefore, the optimal price is at least $\hat{p}_a$. Because the profit function is concave, in this case, $\hat{p}_a$ must be the optimal price. It turns out that, for uniform distribution, $p_r > \hat{p}_a$, and therefore, for $\lambda \in (\lambda_1, \lambda_2)$, the optimal price is p_r. If $p_r \in (\hat{p}_a, \hat{p}_b)$, then the self-control issues are not relevant, and the optimal price is p_r. Thus, as long as $\lambda \in (\lambda_1, \lambda_2)$, sunk cost bias negates the effects of self-control issues, and the firm prices as if consumers do not have self-control issues. However, if $\lambda > \lambda_2$, then $p_r > \hat{p}_b$, and overconsumption becomes a problem. In this situation, the firm wants to reduce prices. Therefore, in this case $p^* \leq p_r$. If $p_r \in (\hat{p}_b, \hat{p}_c)$, then the firm either charges $\hat{p}_b$ so that overconsumption is not an issue or charges a higher price at which some consumers abstain to avoid overconsumption. Suppose λ is large enough such that $p_r > \hat{p}_c$. In this case, only consumers who overconsume and have sufficiently high valuations buy the product. The firm can set price to maximize $(1 - v_4)(p - c)$ or set a price below $\hat{p}_c$ to reduce overconsumption such that the demand is $1 - v_3 + v_2 - v_4$. For the uniform distribution, $(1 - v_4)(p - c)$ is maximized at p_r, which is independent of λ. Thus, $p^* \leq p_r$.

Now, let us consider demand. Because, for $\lambda > \lambda_2$, an increase in λ aggravates the overconsumption problem, intuition suggests that demand and welfare decrease with λ. This is because consumers anticipate overconsumption and can forego purchase. The intuition is only partly correct because it does not take into account that the firm can strategically adjust its prices. It turns out that there is a range of λ in which the firm's prices decline with λ such that the demand *increases* as λ increases. In other words, the pricing effect dominates the direct negative effect of λ on demand. In such a case, social welfare also increases. This result shows that, even when λ is high and the product resembles a vice good, an increase in the sunk cost bias can increase social welfare. The final part of the proposition shows that the firm is hurt by an increase in λ. This is intuitive because an increase in λ increases the overconsumption problem, and the firm, therefore, charges lower prices to incentivize sales and mitigate the negative effect of sunk cost bias on demand.

5. Model Extensions

In the base model, we make several assumptions. Our base model assumes that consumers have rational expectations. In Section 5.1, we relax this assumption and explore how the results change when consumers do not form correct expectations. This analysis allows us to understand the role of expectations on optimal prices, profits, and welfare. In the base model, we assume that the product is only consumed in one period. In Section 5.2, we relax this assumption. Furthermore, we incorporate the idea the sunk cost effects decline over time because of payment depreciation (Gourville and Soman 1998). This allows us to explore the possibility of a multiperiod plan. Our base model considers a monopolist. We extend the analysis to the case of competition in Section 5.3 and explore how sunk cost effects and time-inconsistent preferences can affect the nature of competition.

5.1. Consumers Have Incorrect Expectations

The base model assumes that consumers can perfectly predict their future actions because they are aware of their biases. In reality, this may not be the case. For example, prior research shows that consumers often underestimate their self-control problems (see, for example, O'Donoghue and Rabin 2001, DellaVigna and Malmendier 2004). To model this, we assume that consumers expect the bias parameters to be β^e and λ^e. Prior research suggests that $\beta^e \geq \beta$, that is, consumers underestimate their bias. In a similar vein, we assume that $\lambda^e < \lambda$, that is, consumers do not fully appreciate the level of bias. Thus, if $\lambda^e = 0$ and $\beta^e = 1$, then consumers are not aware of either bias.

To analyze this case, first note that most of the analysis for firm profits and prices remains the same except that we need to replace λ with λ^e and β with β^e. However, incorrect expectations affect optimal prices, profits, and welfare. Because previous research studies the impact of β^e, we focus on the impact of incorrect expectations of sunk cost bias. In particular, we consider two cases. First, we assume that $\beta^e = 1$, that is, consumers do not perceive a self-control problem. Next, we consider the case when $\beta^e = \beta$, that is, consumers have correct expectations of their self-control bias but may not have correct expectations about the sunk cost bias.

Let's first consider the simplest case when $\beta^e = 1$ and $\lambda^e = 0$. In this case, consumers are not aware of their biases. Thus, consumers ignore the usage constraints and only look at the price under the assumption that they will use the product only when the costs are low. Consequently, prices and profits do not depend on the actual level of bias. The firm charges p_r, which is defined in (7). However, welfare is still affected because actual consumption decisions are based on β and λ and not on β^e and λ^e. In particular, a consumer uses the product under low cost only if $\beta v - \kappa + \lambda p_r \geq 0$. If $p_r < \frac{\kappa(1-\beta)\alpha}{\beta}$, then as in Proposition 3 for small values of λ, the usage constraint binds. Consequently, some consumers buy the product and not use it. In this case, a small increase in λ^e has no impact on either usage or the firm's pricing.

Now, consider the case when consumers have correct expectations about the self-control parameter, that is, $\beta^e = \beta$, but underestimate the sunk cost bias, that is, $\lambda^e < \lambda$. As before, incorrect expectations weakly hurt welfare. Let us examine how the optimal prices and profits vary with λ^e. First, consider the case when $\lambda^e < \lambda$ so that consumers underestimate the sunk cost bias. If λ is small and $p_r < \frac{\kappa(1-\beta)\alpha}{\beta}$, then from Proposition 3, we know that the optimal price $v_3 = v_1^e$, where $v_1^e = \frac{\kappa - \lambda^e p}{\beta}$. Thus, the firm charges a price $\hat{p}_a^e = \frac{\kappa\alpha(1-\beta)}{\lambda^e\alpha+\beta} > \hat{p}_a$. In other words, underestimation of sunk cost effect leads to higher prices. Furthermore, note that $v_1(\hat{p}_a^e) < \hat{v}_1$. Thus, for small λ when $\lambda^e < \lambda$, prices are higher. Because the firm wants to charge p_r but in order to induce effort charges $\hat{p}_a^e > p_r$, the firm's sales and profits are lower. However, there is no underconsumption or overconsumption among those who buy. Nevertheless, consumer and social welfare declines because prices are higher and demand is lower. Thus, we have the following result.

Proposition 6. *If $\lambda < \lambda_1$ and $p_r < \frac{\kappa(1-\beta)\alpha}{\beta}$, then underestimation of the sunk cost bias leads to higher prices, lower sales, lower profits, and lower welfare.*

This result is in contrast to earlier research in the context of self-control problems, which suggests that underestimation of the self-control bias can be exploited by firms and lead to higher profits (e.g., DellaVigna and Malmendier 2004, Eliaz and Spiegler 2006, Heidhues and Kőszegi 2010). In contrast, we find that, for low values of sunk cost bias, the firm is hurt by such underestimation. The reason is that such underestimation can reduce sales because consumers may not buy the product incorrectly believing that they will not use the product.

Now consider the case when the sunk cost bias is large, that is, $\lambda > \lambda_1$. In this case, our analysis for a uniform $F(\cdot)$ shows that overconsumption can be a problem and an increase in λ hurts profits. Therefore, when $\lambda^e < \lambda$, consumers may purchase products under the false impression that they will not overconsume but do so. Thus, for larger values of sunk cost bias, underestimation improves firm's profits but hurts welfare.

5.2. Multiperiod Consumption

Now, we consider the case when the consumer uses the product for multiple periods. We assume that the consumer must incur a cost for each time of usage. For example, a consumer who has a gym membership needs to incur costs to visit the gym every time the consumer wishes to exercise. When the consumer can use the product for multiple periods, there is possibility that the product is used only in some of the periods. Therefore, we need to account for partial consumption. Gourville and Soman (1998) find that, if payments (which are sunk costs) are separated over time, the impact of payment on consumption decreases. In other words, the sunk cost effect declines over time. They label this phenomenon as payment depreciation. We incorporate this in our formulation by assuming that, if the consumer paid price p in period 2, then the payment is depreciated by $\eta < 1$ in period 3. In order to simplify the presentation, we consider the case when the consumer can use the product over two periods, periods 2 and 3, and the benefits are realized in period 4. We also assume that overconsumption is not an issue and set $\alpha = 1$. We later discuss how the results change when overconsumption is an issue.

If the firm charges a price p, then the consumer with valuation v uses the product in the second period if $\beta v - \kappa + \lambda p > 0$. Thus, a consumer uses the product in the second period if $v \geq \frac{\kappa - \lambda p}{\beta} \equiv v_{1p}$.[4] The consumer continues to use the product in the third period if $\beta v - \kappa + \eta\lambda p \geq 0$. This reduces to the condition that $v \geq \frac{\kappa - \eta\lambda p}{\beta} \equiv v_{1f}$. Because $v_{1f} > v_{1p}$, consumers with $v \in (v_{1p}, v_{1f})$ only partially use the product. The consumer who fully uses the product is willing to purchase only if $2(v - \kappa) - p \geq 0$, that is, if $v \geq \frac{p}{2} + \kappa \equiv v_{2f}$. Similarly, the consumer is willing to purchase with partial usage only if $v \geq p + \kappa \equiv v_{2p}$. The firm's pricing policy determines whether the marginal consumer partially or fully uses the product. Let p_{rf}^* be the optimal price when the marginal consumer uses the product fully and the usage constraint does not bind. This is given by

$$p_{rf}^* = \operatorname*{argmax}_p (1 - F(v_{2f})). \tag{9}$$

As before, p_{rf}^* is feasible only when p_{rf}^* is such that the marginal consumer is willing to use the product in

both periods. Similarly, define p^*_{rp} as the optimal price when the marginal consumer uses the product only in one period. From our previous analysis, we know that the firm does not charge a price below a certain threshold for partial and full usage. This threshold is determined by equating v_{1f} and v_{2f} for the full usage case. Let this price be denoted by $\hat{p}_{af}$. It is given by

$$\hat{p}_{af} = \frac{2\kappa(1-\beta)}{\beta + 2\eta\lambda}. \tag{10}$$

Similarly, define $\hat{p}_{ap}$ as the price that equates v_{1p} and v_{2p}. This is given by

$$\hat{p}_{ap} = \frac{\kappa(1-\beta)}{\lambda + \beta}. \tag{11}$$

The presence of payment depreciation raises the issue whether the firm can do better by delaying payments. For example, firms can use a multiperiod payment plan such that the consumer pays p_1 in period 2 and p_2 in period 3. In practice, firms often offer such payment plans. In this case, the consumer is willing to invest in period 3 if $\beta v - \kappa + \lambda(\eta p_1 + p_2) > 0$. We wish to address whether using such pricing plan can benefit the firm and also examine how it affects welfare.

Recall that sunk cost bias plays a role in pricing when the usage constraint binds. This holds when λ is small and κ is large. We consider when this is the case for the single payment plan and evaluate the optimal payment plan in which the firm allows the consumers to pay in two installments (p_1, p_2). We have the following result.

Proposition 7. *If the consumer needs to exert effort in every period and $p^*_{rf} < \hat{p}_{af}$ and $p^*_{rp} < \hat{p}_{ap}$, then a multiperiod payment plan increases firm profits, total sales, and welfare. Furthermore, there exists a $\eta^* < \frac{1}{2}$ such that total prices are lower under the payment plan if $\eta > \eta^*$ and a η^{**} such that total prices are higher under the payment plan if $\eta \in (\eta^{**}, \eta^*)$.*

The proposition shows that multiperiod payment plans can increase profits and welfare. Note that in our context, because the exponential discount factor is one and the consumer commits to the payment plan in period 1, there is no benefit to such a financing plan except perhaps because of its impact on the consumer's investment behavior. Thus, our results are different from explanations based on financing motives. Prior research shows that delayed payment plans can be exploitative (Heidhues and Kőszegi 2010). In contrast, we show that such plans can be welfare-enhancing. To understand the intuition, note that the condition in the proposition is such that the effort constraint binds for the consumer. In such a case, if the firm chooses to set a single price, then it could set a price such that the effort constraint is just satisfied for the marginal consumer who fully uses the product, that is, $v_{1f} = v_{2f}$. Alternatively, the optimal price is such that $v_{1p} = v_{2p}$. First, consider the case when the marginal consumer fully uses the product. In this case, the single price must be such that the consumer in the third period is willing to exert effort, that is, we need that $\beta v^* - \kappa + \eta\lambda p^* = 0$, where p^* is such that $v_{1f} = v_{2f}$ and is, therefore, equal to $\frac{2\kappa(1-\beta)}{\beta+2\eta\lambda}$. The second period effort constraint must, therefore, be loose, that is, $\beta v^* - \kappa + \lambda p^* > 0$. Consider an alternate plan $(p^* - \epsilon, \epsilon)$, that is, the consumer pays $p^* - \epsilon$ in period 2 and ϵ in period 3. Under this payment plan, both constraints become loose, that is, $\beta v^* - \kappa + \eta\lambda(p^* - \epsilon) + \lambda\epsilon > 0$. This, however, means that the firm can choose a lower price and serve more consumers. Because $p^*_{rf} < \hat{p}_{af}$, such a price decrease increases firm's profits because of the concavity of the profit function. Consequently, the firm's profits increase, prices decrease, and both consumer and social welfare increase.

Figure 7 shows the optimal payment plan. Note that, in general, the firm charges a higher price in the first period and lowers the price in the second period. This is similar to the pricing structure of gym memberships, for which there is an initial sign-up fee, followed by monthly fees. Also, note that, as the payment depreciation increases, that is, η decreases, the payment in the second period increases. This is intuitive because a decrease in η require a higher price in order to induce usage.

The next part of the proposition shows that total prices that a consumer pays can increase with a payment plan. This happens when the firm can increase prices under the payment plan and induce consumers to fully use the product rather than partially use the product in the single payment case. Thus, such increases are not exploitative. Figure 8 shows how the total prices differ under the single period and

Figure 7. (Color online) Optimal Multiperiod Payment Plan

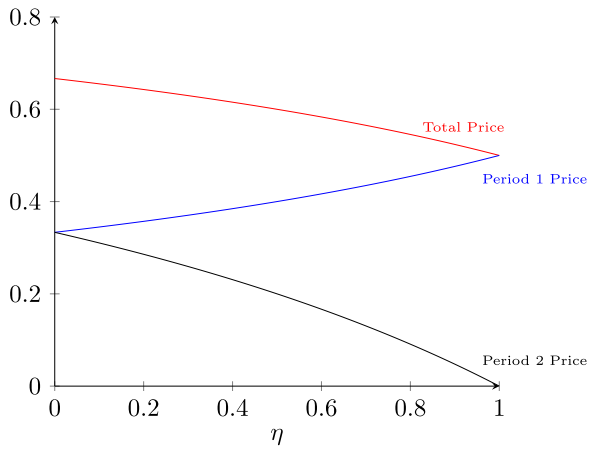
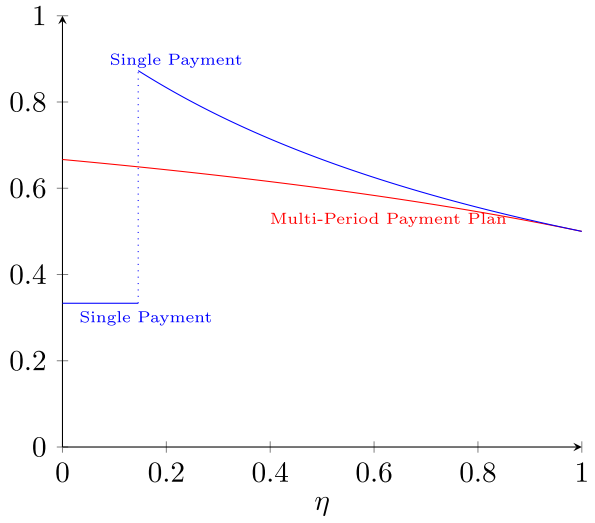


Figure 8. (Color online) Pricing Under Multiperiod Payment Plan vs. Single Payment



multiperiod payment plans. When η is small and, therefore, payment depreciation is significant, the firm is only able to induce partial usage with a single period plan. As η increases, the firm is able to induce full usage. This leads to a discontinuity in the optimal prices as can be seen in Figure 8. For the multiperiod plan, when η is small, if the firm is able to induce full usage, it increases its price and at the same time increases demand.

Now, we briefly discuss the case when $\alpha > 0$, that is, overconsumption is a possibility. It is easy to see that, if consumers overconsume in a single period payment plan, then a multiperiod payment plan can lead to a reduction in overconsumption. Thus, even in such cases, use of a multiperiod plan can be profit- and welfare-enhancing.

The proposition highlights a unique role for payment plans for durable goods in creating value by incentivizing effort when self-control issues are present. This is because, in order to increase usage, thereby increasing value, the firm can better exploit the commitment power of prices in the presence of sunk cost bias if it can make prices more salient. By spreading payments over time, the firm can increase usage in later periods. Interestingly, the results show that such deferred payments can lead to reduction in total payment because this can increase sales and profits for the firm!

5.3. Competition

First, consider the case when the firms are undifferentiated. In general, we expect that competition leads to marginal cost pricing. However, in this case, it is not true, and even though both firms are undifferentiated, they charge a price that is strictly greater than the marginal cost. The equilibrium is a mixed strategy pricing equilibrium in which firms randomize over $(p_m, \hat{p}_a)$, where $p_m > c$ (see Online Appendix B for a formal proof). Therefore, when consumers have self-control and sunk cost bias, undifferentiated firms can make positive profits.

Now, consider the case when there is some differentiation between the two firms. Suppose a consumer at a location θ values firm 1's product at $u - t\theta$ and firm 2's product at $u - t(1-\theta)$, where θ varies across the population according to a distribution $F(\cdot)$ with range (0, 1). In order to model symmetric firms, we assume that $F(\cdot)$ is a symmetric log-concave distribution. This includes the uniform distribution, several families of beta distribution, and the truncated normal (Bagnoli and Bergstrom 2005). The parameter t is a measure of competitive intensity.[5]

As in the base model, assume that the cost of usage can be either high or low. With probability α, the cost is κ, and with probability $(1-\alpha)$, it is u. Thus, no consumer should invest when the costs are high. We assume that, absent self-control problems, consumers use the product when the costs are low, that is, $u - t > \kappa$. However, $\beta(u - \frac{t}{2}) - \kappa < 0$. Thus, consumers in the middle of the Hotelling line would not invest because of self-control issues. Absent any self-control issue, the equilibrium price is $p_o^c = \frac{\alpha t}{f(\frac{1}{2})} + c$. We assume that this price is feasible, that is, consumers at the middle of the line segment are willing to purchase at this price.

The consumer chooses to invest effort in time period 1 when the costs are low if $\beta(u - t\theta) - \kappa > -\lambda p_1$. Define

$$p_a^c = \frac{\kappa - \beta(u - \frac{t}{2})}{\lambda}. \tag{12}$$

Thus, the consumer in the middle of the Hotelling line invest under low costs only if $p \geq p_a^c$. The consumer considers buying at a price p_a^c only if

$$\alpha(u_0 - t\theta - \kappa) - p_a^c \geq 0. \tag{13}$$

This reduces to the condition that $\lambda > \lambda_1^c$, where $\lambda_1^c = \frac{\kappa - \beta(u - \frac{t}{2})}{\alpha(u - \frac{t}{2} - \kappa)}$. If $\lambda < \lambda_1^c$, then firms do not directly compete with each other, and the analysis for the monopoly case holds. Note that p_a^c is decreasing in λ, but p_o^c is independent of λ. By assumption, self-control problems are severe enough that consumers in the middle do not invest when λ is small. Therefore, there exists a λ_2^c such that, if $\lambda > \lambda_2^c$, then price p_o^c leads to effort by consumers under low costs. This is the equilibrium price till the point at which λ is so high that some consumers overconsume and, therefore, abstain from consumption. The following result characterizes the equilibrium.

Proposition 8. *The equilibrium price is*

$$p^* = \begin{cases} \hat{p}_a = \dfrac{\kappa\alpha(1-\beta)}{\lambda\alpha+\beta} & \text{if } \lambda \in (0, \lambda_1^c) \\ p_a^c = \dfrac{\kappa - \beta\left(u - \dfrac{t}{2}\right)}{\lambda} & \text{if } \lambda \in (\lambda_1^c, \lambda_2^c), \\ p_o^c = \dfrac{\alpha t}{f\left(\dfrac{1}{2}\right)} + c & \text{if } \lambda \in (\lambda_2^c, \lambda_4^c) \end{cases} \tag{14}$$

where $\lambda_1^c = \frac{\kappa-\beta(u-\frac{t}{2})}{\alpha(u-\frac{t}{2}-\kappa)}, \lambda_2^c = \left[\frac{\kappa-\beta(u-\frac{t}{2})}{c+\frac{\alpha t}{f(\frac{1}{2})}}\right], \lambda_3^c = \frac{(1-\beta)u}{\frac{\alpha t}{f(\frac{1}{2})}+c}$ *and* $\lambda_4^c = \frac{\alpha\beta(u-\kappa)+(1-\beta)u}{\frac{\alpha t}{f(\frac{1}{2})}+c} - \beta$.

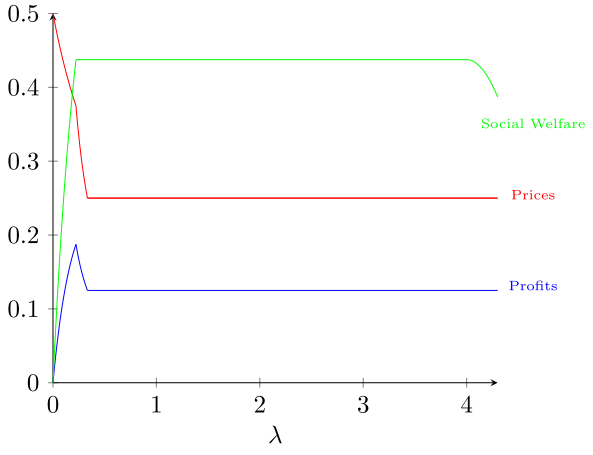
a. *Prices are weakly decreasing when consumer and social welfare are weakly increasing in* λ *for* $\lambda \in (0, \lambda_3^c)$. *Social welfare decreases when* $\lambda \in (\lambda_3^c, \lambda_4^c)$.

b. *Firms' profits increase in* λ *for* $\lambda \in (0, \lambda_1^c)$ *and decrease for* $\lambda \in (\lambda_1^c, \lambda_4^c)$.

c. *As* κ *increases, that is, cost of usage increases, firms' profits weakly increase.*

Figure 9 illustrates the equilibrium prices and profits as a function of λ. We see that prices are decreasing as λ increases. However, this decrease is sharper when $\lambda > \lambda_1^c$. The reason is that, when $\lambda > \lambda_1^c$, firms begin to compete with each other. In contrast to our results from monopoly, when $\lambda \in (\lambda_1^c, \lambda_4^c)$, firms' profits decline. This is because, unlike the monopoly case, a decrease in price does not lead to an increase in sales because the firms split the market among each other. Consequently, an increase in the sunk cost bias leads to lower profits for the firm. In contrast, consumer welfare is positively impacted by this decrease in prices as long as $\lambda < \lambda_3^c$. When λ becomes higher, then when firms continue to decrease prices, some consumers begin to overconsume. This negatively hurts welfare.

Figure 9. (Color online) Prices, Profits, and Social Welfare in a Duopoly



It is also useful to note that our earlier result that prices do not change with marginal costs for a range of parameter still holds. In particular, when $\lambda \in (0, \lambda_2^c)$, prices do not depend on marginal costs. The reason is that, in this case, the firms are motivated to keep prices high enough that the sunk cost bias leads to investment in effort. Because the investment decision is independent of c, the prices are not impacted by c. The result also shows that a decrease in κ leads to lower profits. The reason is that, when κ is low, the prices that firms are able to coordinate to induce effort are lower, and therefore, firms make lower profits. Thus, as in the monopoly case, we find that an increase in quality can lead to lower prices and lower profits.

Proposition 9. *If* $\lambda \geq \lambda_4^c$ *and* $F(\cdot)$ *is uniform, then in any symmetric pure strategy equilibrium, prices, profits, sales, and social welfare decline as* λ *increases.*

Thus, the proposition shows that, when λ is so high that overconsumption is an issue, firms charge lower prices. Note that consumers who have high valuations purchase the product despite overconsuming. Because the firms reduce the prices, the set of consumers who overconsume increases. This hurts social welfare. Furthermore, even though the prices are lower, sales decline because consumers forego purchase to avoid overconsumption. Consequently, both social welfare and profits decline. Taking the results from Propositions 8 and 9, we see that an increase in sunk cost bias hurts firms in competition but could sometimes improve welfare by solving consumer's self-control problems. However, when sunk cost bias is large, both the firm and society are hurt by an increase in sunk cost bias.

6. Conclusion

The purpose of this paper is to explore the impact of sunk cost bias in situations in which consumers have time-inconsistent preferences. Consistent with the conjecture of Nozick (1994), we experimentally demonstrate that sunk costs can lead to higher effort and increased payoffs for subjects. We then explore the implications of this phenomenon for firm's optimal pricing strategies.

Our results provide several interesting insights. We show that, in the presence of sunk cost bias and self-control problems, higher prices can lead to higher experienced quality. Thus, our results suggest that consumers who buy more expensive products might experience higher benefit and be more satisfied with their purchase compared with consumers who buy a cheaper product with equivalent objective quality. We further show that sunk cost bias can sometimes alleviate self-control problems and lead to higher profits for

the firm as well as higher social welfare. Thus, the results show that, in some situations, one bias can counteract the negative effect of another consumer bias. Our results add to the literature on sunk cost bias, which has primarily viewed sunk cost bias as hurting welfare. In contrast, we show that, under some conditions, sunk cost bias can be welfare enhancing. However, consistent with prior research, we find that at very high levels of sunk cost bias, consumers might overinvest, and in such cases, sunk cost bias can lead to reduced profits and welfare.

Our results have important managerial implications. In particular, our results show that, in product categories in which self-control is an issue, firms should carefully choose prices because common intuition about the impact of price and quality on demand does not necessarily hold. Firms can increase customer satisfaction, usage, and demand by increasing prices. Furthermore, our analysis also reveals that, for low values of sunk cost bias, price can be a substitute for quality. In other words, firms may invest less in increasing ease of use and instead increase prices to increase experienced quality. We also find a unique role of payment financing plans that are commonly observed in the marketplace. These financing plans are often viewed as exploitative especially when consumers have time-inconsistent preferences (e.g., Heidhues and Kőszegi 2010). In contrast, we show that such pricing plans can lead to lower prices, increase usage, and lead to higher profits and social welfare.

Our paper has several limitations that can be explored in future research. Our experimental results are consistent with the idea that sunk cost effects can lead to subjects exerting more effort but leave open the possibility that our results can be explained by other rival explanations. Future research can explore this issue.[6] In this paper, we focus on firm's pricing decisions. Sunk cost effects and present-biased preferences can also affect firm's product design and advertising decisions. We also consider situations in which sunk cost bias and present-biased preferences do not vary across consumers. If there is variation in these parameters, this raises the possibility of providing menus of products and prices. This is an interesting avenue of future research. Our paper also provides several results that could be subjected to empirical tests.

Acknowledgments

The authors thank Yi-Na Li for her help with data collection. The authors also thank the editor, the associate editor, and three anonymous reviewers for their insightful comments. The usual disclaimer applies.

Endnotes

[1] The degrees of freedom are smaller because of missing data points.

[2] We do not allow two-part tariffs as in DellaVigna and Malmendier (2004) and Xing et al. (2019) because, for most durables, the firm cannot observe usage and condition pricing on that. Our results are also applicable to service contracts in which usage may be too expensive to track or the firm sets the per-use price to be zero for other reasons.

[3] We see later that this no longer holds when there is a sunk cost effect.

[4] Alternatively, one could argue that, because the product is used for two periods, the relevant price in each period should be $\frac{p}{2}$, and therefore, the sunk cost bias should be $\frac{\lambda p}{2}$. This, however, does not change the analysis because it is equivalent to a rescaling of the sunk cost parameter to $\frac{\lambda}{2}$.

[5] We could normalize $u = 1$ and the key results would hold as long as t is not too large.

[6] Specifically, even though regret as a proxy for sunk cost mediates the effect of price on payoff (though at a marginally significant level), our results could potentially be explained by other psychological mechanisms, for example, anchoring (Tversky and Kahneman 1974). One may argue that the participants in our experiment may have anchored their effort on the price they paid and that is why those who paid a higher price spent more effort (and made more money). Whereas not entirely inconsistent with our sunk cost argument, this rival explanation may imply a more subconscious process in that participants may not have realized the anchoring effect of the price (in the same vein that real estate professionals are unaware of the anchoring effect of a listing price; Northcraft and Neale 1987). In contrast, our explanation based on sunk cost relies on a more conscious process whereby participants who paid more tried harder in order to get their money's worth. Whereas our regret measures seem to support the idea of a conscious process and that our results are driven by sunk costs, future empirical work can try to distinguish this and other possible explanations of our findings.

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