Demonstrations and Price Competition in New Product Release

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Abstract

We develop a game theoretic model of price competition in which an innovating firm can offer product demonstrations before consumers commit to a purchase decision. The firm controls both the informativeness of its demonstration policy (e.g. how much interaction to provide with its product) and the timing of its policy (e.g. whether it commits to a policy before or after prices have been established). We show that the equilibrium demonstration resolves some but not all customer valuation uncertainty. This allows the innovating firm to attract customers without necessarily maximizing differentiation from the established product while maintaining a high price. Consumer surplus may be lower with endogenous demonstrations than without demonstrations. When the innovative firm commits to demonstrations up front, they are always fully informative but consumer surplus is again lower. Also, regulation requiring firms to provide fully-informative demonstrations (e.g., generous return policies or inspection periods) can further reduce consumer surplus. Finally, the ability to design demonstrations creates incentives for innovating firms to limit the market appeal of their products, suggesting another mechanism through which product demonstrations can reduce market efficiency. The results have implications for firm strategies and for consumer protection.

Keywords: price competition, Bayesian persuasion, product demonstrations, trial periods, return policies, test drives

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1 INTRODUCTION

Allowing consumers to learn about their values for a product is an important part of a firm's marketing strategy, implemented in a variety of ways for different types of products. Apple allows consumers hands on interaction with their Macs, iPhones and iPads in the curated environment of their Apple Stores. Other companies design displays and interactive trials, either for their own stores or for "big box" retailers.[1] When a consumer visits a Best Buy, for example, she can try video game consoles, televisions, surround sound systems, phones, and computers. Similarly, wineries or other food producers visit grocery stores to provide tastings of their products. Automakers offer test drives. Software companies offer trial periods.

The informativeness of these demonstrations varies. Some pre-purchase demonstrations only allow for limited interactions prior to purchase. For example, an in-store display at Best Buy may merely display a video of gameplay footage, or it may not allow consumers to play their game of choice on the video game console, limiting the consumer's ability to learn about the console's capabilities. Auto dealers typically choose the route and duration of test drives, which may limit a driver's ability to learn about all aspects of the car's performance. Trial software often offers only a limited set of features. Unlike the preceding examples, in which a consumer's pre-purchase interaction with the product is limited, producers of innovative personal hygiene products, household cleaning supplies, exercise equipment, and a variety of other products often provide money back guarantees or extended trial periods, which resolve most or all of the consumer's valuation uncertainty before the final purchase decision (Heiman et al. 2001). Thus, the degree of information conveyed to consumers before purchase depends on the demonstration design, which is a choice variable for firms.

We present a game theoretic analysis of new product release that incorporates strategically designed product demonstrations into a model of price competition. In our model, one firm sells an innovative product for which customers have uncertainty about their values, and another firm sells an established product of known value. Both firms choose prices for their products. In addition, the innovative firm also chooses a demonstration strategy. Two aspects of the demonstration strategy are novel features of our analysis. First, we allow the firm to control the informativeness of its demonstration: it may provide fully informative demonstrations, which allow consumers to perfectly learn their values, fully uninformed demonstrations, which reveal no information, or levels of informativeness in between these extremes. As described above, demonstration informativeness is influenced by the amount of pre-purchase interaction that the firm allows; the more interaction, the more confident consumers are about their impression of the new product. Second, we allow the firm control over the timing of its demonstration strategy. It can commit to a demonstration policy before product release, or it can retain flexibility to choose demonstration informativeness after prices have been established.

The analysis shows that a firm's optimal demonstration policy depends on whether the firm

[1] Manufacturers often design the display space and provide display merchandise for stores. Samsung and Microsoft, for example, sometimes staff their own "mini stores" inside of retailers such as Best Buy.

commits to a policy before or after market prices have been established. A firm that waits to determine informativeness until after prices have been set prefers demonstrations which are neither fully informative nor fully uninformative. The firm adjusts the informativeness of its demonstration to make favorable consumers just barely prefer its product over the established alternative. In contrast, a firm that commits to a demonstration policy up front strictly prefers demos to be fully informative. This result is consistent with a firm's decision to commit to unrestricted trials or money back satisfaction guarantees. In both of these situations, the innovative firm uses demonstrations to segment the market between those with favorable impressions and those with bad impressions who will strictly prefer the established alternative. Unlike conventional wisdom that suggests maximum product differentiation to be the preferred strategy, we show that the innovative firm may, at the expense of maximum product differentiation, limit informativeness of the demonstration to lower the risk of some consumers not buying the product. Consumers, even though they become better informed, may be made worse off by the presence of demonstrations compared to a setting without demonstrations.

The established firm and consumers may both benefit from commitment to fully informative demonstrations, even in settings where the innovative firm is unwilling to commit. This suggests a potential role for regulation requiring fully informative demonstrations. We show that the established firm always benefits from its competitor providing fully informative demonstrations, providing the established firm incentives to push for regulation or legislation requiring extended return periods or demonstrations, under the guise of strengthening consumer protection. Consumers themselves may also benefit from such a requirement, but only in settings where the innovative firm is unwilling to provide such demonstrations on its own. We show that consumers never benefit from fully informative demos in cases where the innovative firm willingly provides them. Consumers only benefit from such policies in regions of the parameter space in which the firm prefers to retain flexibility and offer only partially informative demonstrations. However, total consumer plus producer surplus is always maximized by regulation requiring fully informative demos.

After establishing these main results, we consider a number of extensions to the model. The majority of the analysis assumes that the innovative firm announces its price and then the establish firm sets it price in response to the entry of the new product. Such an assumption is common in the literature on new product release, including Robinson (1988), Bowman and Gatignon (1995) and Kalra, Rajiv and Srinivasan (1998). Examples include price adjustment by Johnson and Johnson in response to new product release by Bristol-Myers Squib, and Caterpillar lowering price when John Deere and Co. released new industrial equipment. More recently, Microsoft and Sony engaged in game console price reductions in response to new product release by the other firm.[2] In Section 7, we consider the alternative assumption of simultaneous price competition, which may arise if the firm is unable to credibly announce its price in advance.[3] We characterize all pure strategy

[2]See http://www.telegraph.co.uk/technology/video-games/e3/10112334/E3-2013-Sony-reignites-console-price-war-with-Microsoft.html.

[3]We thank the review team for suggesting this pricing game and are able to show that the qualitative insights are not affected.

equilibria and show that, unlike sequential pricing, the firm strictly prefers to retain flexibility in its demonstration design. In these equilibria, demonstrations only partially resolve uncertainty, and consumers are adversely affected by the presence of demonstrations; furthermore, consumers always prefer commitment to fully informative demonstrations even though the firm chooses to provide partially informative demonstrations only.

In Section 8, we consider alternative versions of the model in which the firm strategically chooses the quality of its product. In our model the innovation's quality is composed of two attributes: the share of the market that will benefits from the innovation, and the innovation's value added over the established product. We consider the innovating firm's choice of each quality attribute. From the perspective of the innovating firm, the two quality attributes are complementary for increasing profit. When value added is high, the firm is best off producing a product that benefits all customers. However, when the value added of the innovation is low, the firm's profits are maximized when the product benefits only a portion of consumers. Interestingly, the firm sometimes prefers to develop a product with uncertain appeal rather than one which all consumers are certain to prefer to the established alternative, even when increasing appeal is costless. This is because, by targeting a small portion of the market, the innovative firm can avoid a price war with the established firm. We also show that incentives to limit appeal do not arise in the absence of demonstrations, suggesting an important link between the availability of product demonstrations and the release of products that benefit only a fraction of consumers. This illustrates a way in which pre-purchase demonstrations may reduce total surplus: they can decrease incentives for innovating firms to release widely appealing products. Finally, when the innovative firm can invest in improving the value added of its product, consumers are never hurt and may be better off with fully informative demonstrations, and in some instances commitment to fully informative demonstrations may be Pareto improving, simultaneously making customers and both firms better off compared to the game in which the firm adjusts the informativeness of its demonstrations after price competition.

2 LITERATURE REVIEW

A number of papers consider information provision in monopoly. Lewis and Sappington (1994) consider a seller that allows buyers to acquire private information about their value for an item prior to purchase. They show that a monopolist either allows consumers to become fully informed about their values or provides consumers with no additional information. Schlee (1996) considers a related setting, in which neither the monopolist nor the consumers know the consumers' value for the good, showing that while the monopolist benefits from the release of public information about this value, it may be either beneficial or harmful to consumers. Villas-Boas (2004) considers the interaction of informative advertising that communicates a product's existence with a monopolist's choice of product line offerings, showing that the need to pay a cost to inform consumers causes a monopolist to under-provide product variety. In a recent paper, Gill and Sgroi (2012) allow firms to conduct publicly observable product tests and find that the firms will either choose the most informative or least informative test. Related results are presented by Johnson and Myatt (2006) who extend the binary framework of Lewis and Sappington, developing a general framework for analyzing information provision with a continuum of consumer types. Che (1996) considers the use of customer return policies by a monopolist seller when customers learn about their valuation after purchase. In that paper, a return policy acts as a fully informative demonstration. Ottaviani and Prat (2001) consider a seller with the ability to both supply information and optimally price discriminate, showing that in this circumstance it is optimal to reveal any information affiliated with the buyer's value. We extend the strategic provision of product information to a competitive setting with two firms and show that in the presence of competition, the seller will often choose a signal that conveys some, but not all, relevant information to the buyer.

A significant literature analyzes a monopolist's incentives to signal his private information about product quality through observable actions. For example this signaling role of prices is explored by Bagwell and Riordan (1991) and uninformative advertising is explored by Milgrom and Roberts (1986) and Bagwell and Ramey (1988). Moorthy and Srinivasan (1995) consider money-back guarantees as signaling instruments, showing that the ability to offer a money-back guarantee can allow a monopolist selling a high-quality product to distinguish itself in situations where it otherwise could not.[4] Gardete (2013) considers a model in which a privately informed monopolist sends an unverifiable message of product quality to consumers, showing that despite their unverifiability these messages can be informative to consumers and profitable for firms. In our analysis, valuation uncertainty is only about consumer tastes or needs, and the firm does not have any private information about these attributes. Thus, in our model, information provision (generous return policy, money-back guarantee, etc.) allows the consumer to learn about the match between the product and her tastes and needs before finalizing the purchase, but it does not convey the firm's private information (because it has none).

A number of analyses consider the interaction of information provision and other aspects of firm competition. Moscarini and Ottaviani (2001) consider price competition between firms when buyers learn about their value for a product prior to purchase. In contrast to our analysis, Moscarini and Ottaviani take the informativeness of product demonstrations as exogenous, while in our model the informativeness of a product demonstration is strategically selected by the innovative firm. Iyer, Soberman and Villas-Boas (2005) consider a model of firm competition with targeted advertising (which informs consumers of product existence) and targeted prices, showing that the ability to target advertising to consumers is an important channel to soften price competition. Meurer and Stahl (1994) analyze a related model, in which firms send messages to consumers that perfectly reveal which product the consumer prefers. Unlike our analysis, messages are perfectly informative, and neither demonstration informativeness nor timing act as strategic instruments. The seminal analysis of Shaked and Sutton (1982) demonstrates that quality differentiation arises naturally in equilibrium to soften price competition. Supplying information about product attributes creates differentiation in consumer valuations, however, in our analysis it is not necessarily true that this differentiation is as large as possible. This arises only when the firm prefers to commit initially to a

[4]Related issues are addressed by Grossman (1981) who considers the signaling role of product warranties.

demonstration; when the firm retains flexibility, it does not differentiate its product to the maximum possible extent. Kuksov and Lin (2010) consider information provision decision by two competitive firms when customers have uncertainty about product quality, their preference (valuation) for quality, or both. The paper examines incentives for the firms to provide information that resolves uncertainty on both of these dimensions, and discusses the role of price competition and free-riding on the equilibrium decisions. Important differences exist between this analysis and our paper. While Kuksov and Lin (2010) model two types of uncertainty, a consumer has the same valuation ("preference level for quality" in their terminology) for each product (though vertical qualities can differ); therefore, the provision of valuation information by one firm also resolves uncertainty about the valuation for the other firm's product. Moreover, if a decision is made to provide information, it fully reveals the consumer's valuation, eliminating any uncertainty consumers face about their valuations. In contrast, only the innovating firm's product has an uncertain valuation in our model, and our focus is on the design of the profit-maximizing demonstration, which (it turns out) may be only partially informative. We also consider the timing of demonstrations, identifying conditions under which it is beneficial for a firm to commit to a demonstration design up front, rather than retain flexibility to design a demonstration after prices have been determined. To our knowledge, this question is novel in the literature.

Our analysis considers the strategic design of product demonstrations, both with respect to their informativeness, and with respect to their timing. An emerging literature considers the strategic design of informative an informative signal by a "sender" who wishes to influence the actup frontions of a "receiver" who observes the signal's realization. Kamenica and Gentzkow (2011) and Rayo and Segal (2010) consider strategic signal design by a single sender and receiver. Boleslavsky and Cotton (2014*b*) model signal design in an environment in which two senders try to influence a single receiver. These models focus on the optimal design of signals, and limit competition to be exclusively through the provision of information. Boleslavsky and Cotton (2014*a*) consider the interaction of a strategic signal design problem with incentives for up front investment in improving quality.

3 A MODEL OF PRODUCT RELEASE WITH DEMONSTRATIONS

We consider market competition between two firms: firm α offering an established product, and firm β offering an alternative, innovative product for which consumers are uncertain about their valuation. A continuum of ex ante identical consumers exists, normalized to total mass of one. Each consumer shares a common value $v_\alpha = 1$ for firm α's established product. At the same time, consumers and firms are uncertain about each consumer's value for firm β's product. This value can be either high with $v_\beta = \nu > 1$, or low with $v_\beta = 0$. It is common knowledge that an individual consumer's value for the innovation is an independent realization of a binary random variable with

$$\Pr(v_\beta = \nu) = \theta \quad \text{and} \quad \Pr(v_\beta = 0) = 1 - \theta.$$

Thus θ represents the commonly known *fraction* of consumers with a high value for product β. Neither the firms nor the consumers are initially informed about a particular consumer's value for the innovative product. Note that θ and ν represent different aspects of the innovation product. While θ is a measure of extent of product appeal, ν or $(\nu - 1)$ represents the valuation appeal over the established product. The main analysis focuses on fixed θ and ν, but we consider firm β's choice of θ and ν in Section 8.

Each firm $i = \alpha, \beta$ chooses a price $p_i \geq 0$ for its product, which it charges to all consumers. There are no production costs, and therefore firm i's profit is equal to its price, multiplied by the portion of consumers that buys its product (its market share). In the main analysis, we focus on sequential price competition, in which firm β sets its price before firm α. Firm β announces a price when it releases its product, and then firm α adjusts the price of its established product to account for the entry of the new product into the market. This sequential timing is consistent with studies of new product entry (e.g. Biggadike 1979, Chen, Smith and Grimm 1992, MacMillan, McCaffery and Van Wijk 1985, Robinson 1988, Kalra, Rajiv and Srinivasan 1998) and can be explained by the fact that the innovative firm tends to set the price for its new product up front and believes that frequent price changes are not possible without alienating consumers.[5] In Section 7, we extend our analysis to the alternative case of simultaneous price competition.

After the firms set prices, each consumer decides whether to purchase product α, product β or neither product. When a consumer purchases a product of value v at price p, she earns payoff $u = v - p$. If the consumer does not make a purchase, her payoff is 0. Consumers have unit demand for the products, and it is only feasible for a consumer to purchase one of them.

Product Demonstrations

Firm β can provide consumers with an opportunity to learn about their value for its product before they finalize their purchase decisions. We refer to these learning opportunities as "demonstrations." As will be described below, our notion of "demonstrations" encompasses a variety of practices that allow consumers to learn about their valuations: these may represent product trials, return policies, satisfaction guarantees, as well as more traditional in-store or at-home product demonstrations.

Formally, a demonstration is modeled as a binary random variable, from which consumers realize either "favorable" (good) or "unfavorable" (bad) impression of product β. A consumer who has a high value for product β always observes a favorable impression. A consumer with a low value for product β, however, may observe either a favorable or bad realization. A low value consumer observes an accurate (bad) signal realization with probability $d \in [0, 1]$ and mistakenly observes a favorable realization with probability $1 - d$.[6] Given demonstration informativeness d,

[5] For example, consumers were upset when Apple dropped price of its new iPhone shortly after release. http://www.macnn.com/articles/07/09/05/iphone.price.drop.redux/.

[6] In the Appendix, we include a general model of demonstrations in which this binary signal structure arises endogenously. For ease of exposition, the technical details are omitted in the main body of the paper.

the distribution of a consumer's posterior valuation generated by the demonstration is given by Γ:

$$\Gamma = \begin{cases} 0 & \text{with probability} \quad (1-\theta)d \\ \nu\frac{\theta}{1-(1-\theta)d} & \text{with probability} \quad 1-(1-\theta)d. \end{cases}$$

With this specification, a consumer who experiences a bad realization of the product is confident that the product is not for him. Meanwhile, a consumer who experiences a favorable realization is (for $d < 1$) left with some uncertainty about whether he or she would have a favorable impression if they continued to interact with the product: a consumer with a favorable experience is uncertain whether he is a high value type, or a low value type who observed an inaccurate impression. In this way, d represents the accuracy or thoroughness of the product demonstration. When $d = 0$, the demonstration is fully uninformative; everyone receives a "favorable" impression from the demonstration, and therefore consumers can infer nothing from the fact that they observe a favorable impression. For higher values of d, consumers who receive a favorable impression of the product are more confident that they have high valuation for product β. The expected valuation of a consumer who experiences a favorable realization is increasing in d. When $d = 1$, the demonstration is fully informative; only those with high valuations receive a favorable impression of the product, allowing a consumer that experiences a favorable impression to infer that he has high valuation.

This class of demonstration designs is most appropriate for innovative products with a number of possible "deal-breaking" attributes or features. A low-valuation consumer does not like one of "deal-breakers" and hence is unwilling to purchase the innovation if this critical attribute of the product is encountered.[7] Meanwhile, a high valuation consumer likes the attributes of the product and could never encounter a "deal-breaking" product attribute. The more the consumer interacts with the product, and as more freedom is allowed in this interaction, the more likely it is that a low-valuation consumer will encounter a deal-breaking attribute. Hence, if a consumer experiences a demonstration with significant freedom and does not encounter a deal-breaking feature, the consumer rationally infers that he or she is more-likely to have a high valuation for the innovation. Thus, high values of d in the demonstration design represent pre-purchase interactions with significant information content: long return periods, exhaustive money-back guarantees, or extensive in-store or at-home trials . Conversely, low values of d represent pre-purchase interactions with less information: an in-store video of gameplay footage is less informative about a video game experience than an in-store trial, which in turn is less informative than an at-home trial over an extended period (Heiman et al. 2001, Heiman and Muller 1996, Davis, Gerstner and Hagerty 1995).

In our model, firm β controls two critical aspects of its demonstration strategy: demonstration informativeness and demonstration timing. The firm selects the informativeness of its demonstration by choosing d. Demonstrations with higher values of d deliver more information to consumers about their values for the innovation. We also allow the firm to choose the *timing* of its demonstra-

[7]Deal breaking attributes are often encountered in new product releases. When the iPhone was released, for example, some Blackberry users refused to switch to the iPhone merely because they did not like the experience of its virtual keyboard.

tion decision: the firm can either commit to a demonstration policy d up front—before prices are established—or it can retain flexibility in its demonstration policy, choosing the demonstration informativeness after prices are established. If the firm commits up front, we denote the firm's chosen demonstration design by d_c, and we use d to denote a demonstration design chosen after prices are established. In either case, the consumer observes both the informativeness of the demonstration and its realization before purchase.[8]

Timing. Firm β initially chooses whether to make an initial commitment to a demonstration design or not. Following this choice, we move into one of two possible subgames. If firm β chose to commit, we move to a two-stage subgame in which firms choose prices, and consumers make purchase decisions after observing the result of the demonstration (commitment subgame). If the firm does not commit, we move to a three-stage sub-game in which firms choose prices, then firm β chooses a demonstration design, and subsequently consumers make purchase decisions after observing the result of the demonstration (flexibility subgame). In this section, we focus on the case of sequential price setting; in Section 7, we consider the game with simultaneous price competition. The sequence of events is described in more detail below.

Commitment Stage: Firm β chooses whether to commit to a demonstration policy d_c. If it commits, it chooses $d_c \in [0, 1]$, its choice is publicly observed, and the game moves into the commitment subgame, described below. If it does not commit, it retains flexibility to select d, and the game moves into the subgame with demonstration flexibility, described below.

The Flexibility Subgame

1. **Price competition:** The firms set prices sequentially. The new firm sets its price p_β first. The incumbent firm sets p_α in response to the entry of the new product.

2. **Demonstration:** If firm β has flexibility in demonstration design, it now chooses demonstration informativeness $d \in [0, 1]$. Consumers then experience the demonstration (with informativeness d_c in the case of commitment or d in the case of flexibility), receiving a favorable or unfavorable impression of the product. They update their beliefs about their valuations according to Bayes' Rule accounting for both demonstration informativeness and their impression of the product.

3. **Purchase:** Each consumer observes the demonstration design d chosen by the firm, its realization, and prices. The consumer then decides which, if either, product to purchase.

The Commitment Subgame

[8] As described above, demonstration informativeness is affected by the length of time for a return policy, for example. This length of time is observed by the consumer and rationally affects her valuation for the product at the return policy's expiration.

1. **Price competition:** The firms set prices sequentially. The new firm sets its price p_β first. The incumbent firm sets p_α in response to the entry of the new product.
2. **Purchase:** Each consumer observes the demonstration design d_c chosen by the firm, its realization, and prices. The consumer then decides which, if either, product to purchase.

In the flexibility subgame, the last decision before consumers choose a product is taken by firm β: it selects a demonstration design. In the commitment subgame, the last decision before consumers choose a product is taken by firm α: it selects a price for its product.

4 EQUILIBRIUM

We solve for the Perfect Bayesian Equilibrium of the game. We begin by considering the purchase decision of consumers (which is identical in the commitment and the flexibility subgames). We then analyze the equilibrium of the flexibility subgame by backwards induction. Next, we analyze the equilibrium of the commitment subgame, also by backwards induction. Finally, we consider firm β's decision in the commitment stage, by comparing its payoff in the commitment and flexibility subgames.

Consumer Purchase Decision

In the final stage of the game, each consumer i makes a purchase decision. Before doing so, she observes the demonstration design (d in the flexibility subgame and d_c in the commitment subgame) and either a favorable or bad impression of the product generated by the demonstration. She then updates her beliefs about v_β according to Bayes' rule. Let μ_i denote consumer i's expected value for product β after experiencing a demonstration: μ_i equals the realization of Γ for consumer i.

Consumer i's expected surplus from purchasing good β is $u_i(\beta) = \mu_i - p_\beta$, and his expected surplus from purchasing good α is $u_i(\alpha) = 1 - p_\alpha$. If he purchases neither product, his payoff is 0. It is sequentially rational for the consumer to purchase the product that offers the higher expected payoff, provided that this expected payoff is positive. Consumer i therefore purchases product β if

$$\mu_i - p_\beta \geq 1 - p_\alpha \quad \text{and} \quad \mu_i - p_\beta \geq 0$$

and purchases product α if

$$\mu_i - p_\beta < 1 - p_\alpha \quad \text{and} \quad 1 - p_\alpha \geq 0.$$

By setting $p_\alpha > 1$, firm α is guaranteed never to make a sale. These prices are therefore (weakly) dominated by $p_\alpha = 1$. We focus on equilibria in which firm α does not choose a weakly dominated strategy: in equilibrium $p_\alpha \leq 1$. This immediately implies that we can ignore the case in which the consumer purchases neither product, as purchasing α is better than purchasing nothing. Thus, the consumer's purchase decision is determined by a single threshold for her posterior belief: she purchases firm β's product whenever she is sufficiently convinced that her valuation for the innovation is likely to be high. Consumer i purchases product β whenever $u_\beta \geq u_\alpha$ and otherwise purchases product α. Let

$$\bar{\mu}(p_\alpha, p_\beta) \equiv 1 - p_\alpha + p_\beta$$

denote the critical threshold in the posterior belief. The following lemma summarizes consumers' equilibrium strategy.

Lemma 4.1 *(Consumer purchase decision). In equilibrium, consumer i purchases product β if and only if $\mu_i \geq \bar{\mu}(p_\alpha, p_\beta)$. Otherwise the consumer purchases product α.*

Next, we analyze the equilibrium arising in the subgame with demonstration flexibility.

4.1 EQUILIBRIUM UNDER DEMONSTRATION FLEXIBILITY

First, we derive the equilibrium of the subgame in which the firm chooses demonstration informativeness d after prices have been established. This subgame arises if the firm cannot commit or chooses not to commit to a demonstration policy before releasing its product.

Demonstration Design

Firm β designs its demonstration to maximize market share. If it has the flexibility to design its demonstration following price competition, it chooses d while taking into account prices p_α and p_β.

A consumer that receives a bad impression of product β from the demonstration will never pay to purchase the product. A consumer with a favorable impression of β will purchase the product if and only if $\mu_i \geq \bar{\mu}$. This will be the case when the positive realization of Γ is at least $\bar{\mu}$:

$$\bar{\mu}(p_\alpha, p_\beta) \leq \nu \frac{\theta}{1 - (1-\theta)d},$$

which is equivalent to

$$\frac{\bar{\mu}(p_\alpha, p_\beta) - \nu\theta}{\bar{\mu}(p_\alpha, p_\beta)(1-\theta)} \leq d. \tag{1}$$

As long as (1) holds, firm β's market share equals the portion of consumers that receive a positive realization of Γ: $1 - (1-\theta)d$. Therefore, β's market share is decreasing in demonstration informativeness, conditional on the demonstration being "informative enough" that consumers with favorable realizations want to purchase its product.

Firm β chooses a demonstration that is just informative enough that those with favorable realizations choose its product over product α. Doing so maximizes the number of consumers with sufficiently favorable impressions to purchase the product. Then, firm β's best response demonstration to prices p_α and p_β is

$$d^* = \frac{\bar{\mu}(p_\alpha, p_\beta) - \nu\theta}{\bar{\mu}(p_\alpha, p_\beta)(1-\theta)} = \frac{1 - p_\alpha + p_\beta - \nu\theta}{(1 - p_\alpha + p_\beta)(1-\theta)}, \tag{2}$$

when $d^* > 0$. When $1 - p_\alpha \leq \nu\theta - p_\beta$, it follows that $d^* \leq 0$, and the preferred demonstration involves $d = 0$.

The informativeness of β's demonstration strictly increases whenever the innovation appears less desirable after prices are set. This happens when the price of product α falls, when the price of product β increases, or when the expected value of product β (represented by $\nu\theta$) falls. If product β appears more promising, firm β does not need to reveal as much information to consumers about their valuation to be competitive. It can therefore offer a less informative demonstration, generating unfavorable realizations with lower probability, allowing it to sell its product to the larger portion of consumers who observe a favorable realization.

When $\bar{\mu}(p_\alpha, p_\beta) > \nu$, p_α is sufficiently lower than p_β that even consumers who know they have high value for β choose to purchase product α. In this case, firm β earns zero profits independent of its choice of d. Alternatively, when $\bar{\mu}(p_\alpha, p_\beta) \leq \theta$, p_α is sufficiently higher than p_β that all consumers purchase from firm β based on their priors alone. In this case, firm β chooses an uninformative demonstration with $d = 0$.

The following demonstration describes the equilibria of the demonstration subgame, and gives firm profits and consumer surplus in each situation.

Lemma 4.2 *(Sequentially rational product demonstrations)*

- *If $\nu < \bar{\mu}(p_\alpha, p_\beta)$, then firm β is indifferent between all product demonstrations and never makes a sale:*

$$\pi_\alpha = p_\alpha, \qquad \pi_\beta = 0, \qquad CS = 1 - p_\alpha.$$

- *If $\nu\theta < \bar{\mu}(p_\alpha, p_\beta) \leq \nu$, then firm β chooses a restricted demonstration with $d = d^*$ as given by (2). Firm α sells to consumers who receive a bad impression of product β, and firm β sells to those who receive a favorable impression:*

$$\pi_\alpha = (1 - \frac{\nu\theta}{\bar{\mu}(p_\alpha, p_\beta)})p_\alpha, \qquad \pi_\beta = \frac{\nu\theta}{\bar{\mu}(p_\alpha, p_\beta)}p_\beta, \qquad CS = 1 - p_\alpha.$$

- *If $\bar{\mu}(p_\alpha, p_\beta) \leq \nu\theta$, then firm β prefers a completely uninformative demonstration, $d = 0$. Firm β makes a sale with probability one:*

$$\pi_\alpha = 0, \qquad \pi_\beta = p_\beta, \qquad CS = \nu\theta - p_\beta.$$

Interestingly, those consumers who choose to purchase product β do not have a strong preference for doing so. In order to maximize the probability of generating a good realization, firm β designs the demonstration in such a way that a favorable demonstration is "just favorable enough" that the consumers purchase product β.

In the flexibility subgame, the product demonstration is determined *after* prices are chosen. Firms therefore anticipate the impact of prices on the sequentially rational demonstration design, generating interesting incentives. In particular, if it reduces its price, firm α anticipates that firm β will respond by designing a more informative demonstration. The more informative demonstration will generate bad realizations more often, increasing the share of consumers who purchase product α. As we will discuss later in the paper, this type of incentive does not arise if firm β commits up front to its demonstration design.

Price Competition

This section considers sequential price competition, where firm β announces a price for its new product, and the incumbent firm α can then respond by setting a new price for the established product. Here, we assume that firm β chooses a demonstration strategy following the choice of prices by the two firms. Section 7 considers a setting of simultaneous price setting.

In the second half of the pricing stage, firm α chooses p_α having observed p_β, and anticipating firm β's optimal demonstration design in the next stage. When $1 > \nu - p_\beta$, firm α has the ability to set a sufficiently low price as to capture the entire market, including any consumers who know that they have a high value for product β. If firm α sets such a price, firm β will receive zero profit, regardless of how informative it makes its demonstration in the next stage. Firm β recognizes this possibility of losing the entire market and will never set a price p_β for which firm α's best response involves full market capture.

Rather, firm β always prefers a price that does not provoke an aggressive price response from firm α. When it is feasible to do so (when ν is relatively high and θ is relatively low), firm β optimally chooses a price that evokes *no response whatsoever* from firm α. In this case, α observes to the entry of the new product and p_β, and then continues to set the monopolist price, $p_\alpha = 1$. Even when ν and θ are such that α will reduce price in response to new product entry, firm β is careful to avoid creating incentives for α to try to capture the entire market. Rather, β sets the highest possible price that does not result in losing the entire market.

The following result summarizes the relevant outcomes of the game along the equilibrium path, when firm β chooses demonstration strategy following price competition:

Proposition 4.3 *(Equilibrium outcomes under demonstration flexibility). In equilibrium of the game in which firm β chooses demonstration informativeness after price competition, there two possible equilibrium outcomes. In both cases, firm β chooses a partially informative demonstration with $d \in (0, 1)$.*

> ***Non responsive equilibrium:***
> *When $\nu \geq 4\theta/(1 - \theta^2)$, firm β sets a price that evokes no response by firm α. There exists*

values p_β^L and p_β^H such that on the equilibrium path of play:

$$p_\beta \in [p_\beta^L, p_\beta^H], \quad p_\alpha = 1, \quad d = \frac{p_\beta - \nu\theta}{(1-\theta)p_\beta}$$

$$\pi_\alpha = 1 - \frac{\nu\theta}{p_\beta}, \quad \pi_\beta = \nu\theta, \quad CS = 0.$$

The equilibrium in which $p_\beta = p_\beta^H \equiv \frac{1}{2}(v\theta + \sqrt{v^2\theta^2 + 4v\theta})$ is Pareto optimal.

Responsive equilibrium:
When $\nu < 4\theta/(1-\theta^2)$, firm β sets a price that evokes a moderate response from firm α. On the equilibrium path of play:

$$p_\beta = \frac{(1+\theta)^2\nu}{4\theta} - 1, \quad p_\alpha = \frac{(1-\theta^2)\nu}{4\theta}, \quad d = \frac{1}{1+\theta}$$

$$\pi_\alpha = \frac{(1-\theta)^2\nu}{4\theta}, \quad \pi_\beta = \frac{1+\theta}{2}\nu - \frac{2\theta}{1+\theta}, \quad CS = 1 - \frac{1-\theta^2}{4\theta}\nu.$$

In equilibrium, firm β prefers the lowest level of demonstration informativeness, d, such that consumers that experience favorable impressions of its product (weakly) prefer it to the established alternative. When firm α sets a lower price in the previous stage, firm β respond by providing a more informative demonstration. This is possible except when firm α's price is sufficiently low that even customers who are certain that they have a high value for product β prefer product α. In that case, even a fully informative demonstration, $d = 1$, is not sufficient for firm β to capture any of the market.

The only time that it is sequentially rational for firm β to provide a fully informative demonstration is when firm α's price advantage is exactly such that only a consumer who knows it has high value for product β is willing to purchase it. Firm α never prefers to set such a price in equilibrium, since setting a marginally lower price guarantees that firm α captures the entire market, rather than only the $1-\theta$ portion of the market with low value for product β. Therefore, there does not exist an equilibrium in which the firm provides fully informative demonstrations.

Similarly, we rule out equilibria in which the firm provides fully uninformative demonstrations. Firm β prefers an uninformative demonstration only when its price advantage is sufficient that consumers prefer product β based on their priors alone. In such a case, firm α captures none of the market, and can do better by setting a lower price, for which it is a best response for firm β to provide a more informative demonstration.

Equilibria in which firm α captures the entire market are also ruled out because firm β would have an incentive to deviate to provide either a lower price or a more informative demonstration. Therefore, in each equilibrium, firms β provides demonstrations which are neither fully informative nor fully uninformative about the suitability of its product, and firm β sells to those with favorable impressions of its product, and firm α sells to those with bad impressions of its product. This is in contrast to much of the literature on information disclosure in monopoly, which finds that extreme information provision, either full or none, is optimal.

In the "no-response" equilibrium of the game with flexible demonstrations, firm α acts as if it is a monopolist, even though it faces market competition from firm β and receives lower profits as a consequence.[9] At the same time, firm β earns a profit equal to the one he would have had if he were a monopolist. Firm α earns positive profit (but less than its profit as a monopolist). This equilibrium therefore clearly illustrates the possible anti-competitive consequences of product demonstrations. When analyzing the "no-response" equilibrium in the remainder of the paper, we focus on the Pareto optimal equilibrium characterized in the proposition.

In both possible equilibria of the game with flexible demonstrations, consumer surplus is the same as if all consumers purchase product α (and is equal to $1 - p_\alpha$). This is a consequence of the structure of the optimal demonstration. Consumers that realize a bad impression of product β have a strict preference for product α, and consumers with a favorable impression "just barely" prefer product β and receive a payoff arbitrarily close to the payoff they would have received from purchasing product α. Thus, compared to the case in which α acts as a monopolist, any allocative efficiencies that arise from the presence of firm β are appropriated entirely by firm β, and are not passed on to consumers. This is particularly problematic for consumers when firm β is able to enter the market without provoking a price response from α, leaving consumers with the same zero surplus that they expect under monopoly.

4.2 EQUILIBRIUM WITH AN INITIAL COMMITMENT

We now turn out attention to the subgame in which firm β chooses to commit to a demonstration policy before releasing its product. This type of commitment to a demonstration policy may be self-imposed (automakers requiring that dealers offer overnight test drives on a new luxury model, or manufacturers announcing satisfaction guarantees on a new product) or may be due to regulations mandating certain types or demonstration designs, like generous return policies or trial periods (we explore the implication of these types of regulations in greater depth in Section 9. We first determine subgame equilibrium outcomes under for any level of demonstration commitment $d_c \in [0,1]$. Then we determine firm β's preferred level of commitment.

Exogenous commitment

To understand the distinction between an initial commitment to demonstration design and retaining flexibility, we first consider the equilibrium of the subsequent pricing game, assuming that firm β's demonstration design, d_c, is given initially. For the initial discussion, we remain agnostic about the source of this commitment; later in this section we consider d_c to be chosen by firm β.

If firm β is committed up front to demonstration policy d_c, then firm α takes both d_c and p_β as given when choosing its price. Knowing d_c, firm α can predict the willingness to pay of

[9] In our basic model a monopolist endowed with an optimal demonstration technology, would be indifferent over all prices greater than or equal to θ. Firm β's equilibrium behavior is thus consistent with monopoly.

consumers with favorable impressions of product β, and can set a price just low enough to entice all consumers (even those with favorable impressions of β) to purchase product α.[10] Alternatively, firm α could set a price $p_\alpha = 1$, maximizing the profits earned from the market segment that realize bad impressions of product β, but conceding the market segment that have favorable impressions of product β.

Firm β recognizes the potential for firm α to set a low enough price to capture the entire market. When α sets such a price, firm β earns zero profit. Anticipating this, when feasible, firm β sets p_β just low enough that firm α chooses not to go after the entire market, conceding those with favorable impressions to firm β. If firm α goes after the entire market, it must offer consumers with favorable impressions of β a higher surplus from the established product:

$$\frac{\nu\theta}{1-(1-\theta)d_c} - p_\beta \leq 1 - p_\alpha \Rightarrow p_\alpha \leq 1 - \frac{\nu\theta}{1-(1-\theta)d_c} + p_\beta$$

Thus, α's maximum profit from enticing the entire market as a response to p_β is bounded by

$$1 - \frac{\nu\theta}{1-(1-\theta)d_c} + p_\beta$$

If firm α sells only to consumers with an unfavorable view of the innovation, it optimally sets $p_\alpha = 1$, generating profit $(1-\theta)d_c$. Thus, the maximum price that firm β can charge without incentivizing firm α to go after the entire market is equal to:

$$p_\beta = \frac{\nu\theta}{1-(1-\theta)d_c} - (1 - d_c(1-\theta)). \tag{3}$$

When product β is expected to be better ex ante than product α, so that $\nu\theta \geq 1$, a price satisfying this condition always exists, no matter what kind of demonstration design has been chosen. However, when product α is expected to be better ex ante, $\nu\theta < 1$, for firm β to be able to capture any market share, the demonstration design (set initially) must be sufficiently informative:

$$d_c \geq \frac{1-\sqrt{\nu\theta}}{1-\theta}, \tag{4}$$

Thus, when (4) is satisfied, p_β is defined by (3); when (4) is violated, firm β captures no market share and all consumers purchase product α.

Lemma 4.4 *(Commitment subgame). Consider the subgame following firm β's commitment to demonstration design d_c. When (4) is satisfied, the equilibrium path is as follows:*

$$p_\alpha = 1, \qquad p_\beta = \frac{\nu\theta}{1-(1-\theta)d_c} - (1 - d_c(1-\theta)), \qquad \pi_\alpha = (1-\theta)d_c,$$

[10]This is true as long as the consumers prefer product α when $p_\alpha = 0$; that is, when $v_\alpha > \theta/(1-(1-\theta)d_c) - p_\beta$. In equilibrium, firm β always chooses p_β such that this condition is satified.

$$\pi_\beta = \nu\theta - (1 - d_c(1-\theta))^2 \qquad \textit{and} \qquad CS = (1 - d_c(1-\theta))^2.$$

When (4) is violated, firm α captures the entire market regardless of firm β's choice of p_β; here, $p_\alpha = 1$, $\pi_\alpha = 1$ and $\pi_\beta = 0$.

In the equilibrium with commitment, firm α's incentive to drop its price is different than in the equilibrium without commitment. With commitment, firm α is the last mover, and optimally adopts one of two pricing strategies: it either maximizes the profit it obtains from the portion of the market that has an unfavorable experience with the innovation by setting a price of one, or it captures the entire market by setting a sufficiently low price that will attract even the consumers with a favorable view of the innovation. Thus, firm β's equilibrium price is as high as possible while deterring market capture by firm α. This price is equal to the full expected value of consumers with favorable impressions, discounted by $1 - d_c(1-\theta)$—the necessary price reduction that leaves consumers sufficient surplus to deter α from trying to capture them. Firm β collects this price from the fraction $1 - d_c(1-\theta)$ of consumers who receive favorable impressions from the demonstration. Hence, in expectation, firm β's profit is equal to the expected value of the innovation, $\nu\theta$, minus $(1 - d_c(1-\theta))^2$, the ex ante reduction in profit induced by the necessary price drop that is needed to deter firm α.

Firm β's endogenous commitment

Given the continuation subgame following a pre-commitment to demonstration design d_c, characterized in Lemma 4.4, we consider firm β's choice of demonstration design and demonstration timing. If firm β were to commit to a demonstration design up front, choosing a value of d_c violating 4 is suboptimal. Furthermore, with commitment to the demonstration, firm β profit is increasing in the demonstration informativeness, d_c.

With commitment, increasing demonstration informativeness increases firm β's profit. To see this note that an increase in d_c has two effects. First, it increases the valuation of those with a favorable impression of product β; second, it reduces the probability of generating a favorable impression of product β. Both of these effects increase p_β. The first effect does so because consumers with favorable impressions are more willing to pay for the innovation. The second effect does so because a larger d_c means more consumers will learn that they do not like the innovation, leaving α a larger market share, even if it does not try to capture the entire market. Hence, the benefit to firm α from trying to capture the entire market is smaller, so it is less inclined to do so, allowing firm β more freedom to set a higher price. As described above, for any value of d_c, firm β's profit is equal to the expected value of the innovation $\nu\theta$ minus a term, $(1 - d_c(1-\theta))^2$, that reflects the discount it must offer to avoid capture by α. Changes in d_c only affect the second term, and loss of profit decreases in d_c. Hence, when firm β commits to a demonstration policy, it prefers to commit to the most-informative demonstration policy possible.

Proposition 4.5 *(Fully informative demonstration and firm commitment). An up front commitment to a fully informative demonstration design, $d_c = 1$, delivers firm β a higher continuation* *profit than an up front commitment to any other demonstration design. On the equilibrium path:*

$$p_\alpha = 1, \qquad p_\beta = \nu - \theta, \qquad \pi_\alpha = 1 - \theta,$$

$$\pi_\beta = \theta(\nu - \theta) \qquad \textit{and} \qquad CS = \theta^2.$$

Up front commitment to a demonstration and retaining flexibility to design a demonstration after prices have been set generate significantly different equilibrium outcomes. First, note that with up front commitment, the equilibrium demonstration is fully informative. Consequently, consumers who choose to purchase the innovation expect a strictly higher surplus (equal to θ) from purchasing the innovation than from purchasing the established product—indeed, firm β must make the innovation strictly more attractive to these consumers to avoid market capture by firm α. In contrast, with demonstration design after prices, the demonstration ensures that consumers who purchase the innovation are (almost) indifferent between purchasing either product, and, in equilibrium, it resolves some but not all consumer uncertainty about the innovation's value. Second, note that in the commitment equilibrium firm α acts in a non-responsive way, but firm β is unable to secure the monopoly profit (as would happen in the non-responsive equilibrium) and consumer surplus is non-zero. With pre-commitment to demonstration, firm α is the last mover, and it can capture the entire market from firm β if firm β does not leave sufficient surplus to consumers to deter α from profitably taking this approach. Thus, pre-commitment to demonstrations could never be more profitable for firm β than the non-responsive equilibrium (with flexibility). However, it could be more profitable than the responsive equilibrium. With demonstration flexibility, firm α has an incentive to drop its price in order to induce firm β to select a more informative demonstration design; with the more informative demonstration, fewer consumers are expected to like the innovation, increasing α's market share. Indeed, in the responsive equilibrium with flexibility, firm α engages in this type of behavior. In contrast, with up front commitment, this incentive to defend market by dropping price does not exist for firm α, because it is the last mover (and its price therefore does not influence β's demonstration design). In this sense, pre-commitment to demonstration softens competition, which may benefit firm β.

To determine whether the firm prefers to make an initial commitment or retain flexibility, we compare firm β's profit when it commits to optimal demonstration policy before product release (see Proposition 4.5) to its profit when it retains flexibility to choose its demonstration d after prices have been set (see Proposition 4.3). When it commits up front, it prefers $d_c = 1$, and earns profits $\pi_\beta = \theta(v - \theta)$. When it retains flexibility, it earns either $\pi_\beta = \nu\theta$ when ν is sufficiently large, or $\pi_\beta = (1+\theta)\nu/2 - 2\theta/(1+\theta)$ for smaller ν. Comparing the payoffs establishes that firm β is better off committing to a demonstration policy up front whenever the value added of the innovation is not too large:

$$\nu < \frac{2\theta(2+\theta)}{1+\theta}. \tag{5}$$

When this condition is satisfied, the firms optimal demonstration strategy involves committing to a fully informative demonstration strategy prior to product release. This may involve announcing a generous return policy, trial period or satisfaction guarantee with the announcement of its product.

Proposition 4.6 *(Commitment versus Flexibility) When (5) is satisfied, in equilibrium firm β commits to a fully informative demonstration strategy with $d_c = 1$, and outcomes are given by Proposition 4.5. When (5) is not satisfied, in equilibrium firm β retains flexibility to design demonstrations after prices are set, in which case equilibrium demonstrations are neither fully informative nor fully uninformative, and outcomes are given by Proposition 4.3.*

This result illustrates that the freedom to select a demonstration design that is not fully informative is valuable only when coupled with a late timing of demonstration design. Indeed, when the value added of the innovation, ν, is not too large and the general appeal of the demonstration, θ is not too small, the firm prefers to commit to a fully informative demonstration policy with the release of it product. Furthermore, when the innovation's value added is large or it has narrow appeal, the firm prefers to retain flexibility to design the demonstration *after* p_α has been selected. In this later case, the demonstration is not fully informative.

This result also presents an interesting connection to the literature on product differentiation (see for example, the seminal contribution of Shaked and Sutton (1982)), where firms initially differentiate their products, typically to the maximum extent possible, in order to soften price competition. The link between demonstration informativeness and product differentiation is not as straightforward in our model as in the literature.[11] However, in the case of ex ante undifferentiated products, when $\nu\theta = 1$, an increase in demonstration informativeness increases product differentiation.[12] We therefore focus on $\nu\theta = 1$ in this discussion. When the innovating firm commits to design its demonstration up front, (which does happen in equilibrium for high θ, even in the case of $\nu\theta = 1$), the innovating firm chooses a demonstration design that maximally differentiates its product. This is consistent with the results of the product differentiation literature. However, in our model, the firm sometimes prefers to wait to design its demonstration, and in these cases, designs a demonstration that *does not* maximally differentiate its product from the alternative. Thus, retaining flexibility may be valuable to the firm, even at the expense of maximal product differentiation under commitment.

[11] Because a consumer's (expected) valuation for the innovation, Γ is a random variable—it depends on the consumer's impression of the product—the difference between the consumer's (expected) valuation for the innovation and for the existing product, $\Gamma - 1$ is also random. Because the difference in willingness to pay is stochastic, formulating a reasonable measure of product differentiation is less straightforward than in the case of certainty, where the quality difference is a natural measure.

[12] In the case of ex ante undifferentiated products, $\nu\theta = 1$, a link between demonstration informativeness and product differentiation naturally emerges. In this case, $E[\Gamma - 1] = 0$ for all values of d. When $d = 0$, the quality difference random variable $\Gamma - 1 = 0$ with certainty, the case of zero differentiation. Increasing d increases the probability with which $\Gamma - 1$ realizes as -1, and generates a positive mass on realization $\nu\theta/(1 - (1 - d)\theta) - 1 > 0$. Thus (for the case of ex ante undifferentiated products) an increase in d causes both possible realizations of $\Gamma - 1$ to move (weakly) away from zero, while preserving the mean of zero. With ex ante undifferentiated products, increasing informativeness generates a mean preserving spread of random variable $\Gamma - 1$. Thus, any reasonable measure of the variability of $\Gamma - 1$ will increase in this case.

5 WHO BENEFITS FROM PRODUCT DEMONSTRATIONS?

Simple intuition suggests that consumers should be better off (or at least no worse off) when they are able to learn more about their valuations about the innovation prior to purchase. Proposition 5.1 shows that with fixed prices, this intuition is correct.

Proposition 5.1 *(Valuable information with fixed prices). Taking prices p_α and p_β as fixed, increasing fixed demonstration informativeness d_c weakly increases consumer surplus. For all d_c satisfying (1), increasing d_c strictly increases CS and π_α, and strictly decreases π_β.*

The proposition shows that taking prices as given, consumers cannot be made worse off by more informative demonstrations. It also shows that increasing informativeness strictly increases consumer surplus and decreases firm β profits when demonstrations are sufficiently informative that consumers with favorable realizations prefer to buy product β. When consumers with good realizations prefer β under the prevailing prices, further increases in informativeness reduce firm β's market share because fewer consumers with low valuations experience good impressions of the innovation. Thus (given fixed prices) firm β's profit is reduced. Consumers benefit, however, because the low valuation consumers have better information and are less likely to make a mistake by purchasing the innovation.

This result—formalizing simple intuition—overlooks the interaction between firm demonstration policies and price competition. Firms strategically adjust their prices, and in anticipation of demonstrations, are less willing to engage in aggressive price competition in the earlier stage of the game. In this way, product demonstrations weaken price competition, leading to higher prices and lower consumer surplus. Therefore, contrary to simple intuition, providing consumers with demonstrations prior to purchase may not necessarily make consumers better off.

When prices are endogenous but demonstration informativeness is exogenous, d_c, Lemma 4.4 shows that for any informativeness satisfying (4), consumer surplus equals $CS = (1-d_c(1-\theta))^2$, and is therefore strictly decreasing in exposure to information. The negative relationship between consumer information and consumer welfare is in contrast to popular intuition, and is present because our analysis accounts for how equilibrium prices respond to consumer exposure to information. Consumer benefits of better purchase decisions are dominated by the costs to consumers of decreased price competition between the firms. Thus, with endogenous prices, increases in exogenous information provision have adverse consequences for consumers.

We also would like to understand the consequences of product demonstrations for consumers. We therefore compare the game with endogenous product demonstrations to a benchmark, in which firm β must offer a completely uninformative demonstration: $d_c = 0$. With an uninformative demonstration, the firms compete sequentially in prices, a full information, asymmetric, sequential Bertrand game. We describe the subgame perfect equilibria outcome in which consumer surplus is maximized. The subgame perfect equilibrium depends on whether the priors favor product α or product β.

Uninformative Demonstrations:

- If $\nu\theta \geq 1$, then the expected value from purchasing product β is greater than the known value from purchasing product α. In the unique equilibrium, firm β sets the highest price that guarantees it captures the entire market. Here,

$$p_\beta = \nu\theta - 1, \quad p_\alpha = 0$$

$$CS = 1, \quad \pi_\alpha = 0, \quad \text{and} \quad \pi_\beta = \nu\theta - 1.$$

- If $\nu\theta < 1$, then the priors favor product α. In every subgame perfect equilibrium firm β captures zero market share. The equilibrium in which consumer surplus is maximized corresponds to the case with the greatest price competition.[13] Here,

$$p_\beta = 0, \quad p_\alpha = 1 - \nu\theta$$

$$CS = \nu\theta, \quad \pi_\alpha = 1 - \nu\theta, \quad \text{and} \quad \pi_\beta = 0.$$

Thus, as in the simultaneous move Bertrand pricing game, the firm with the product that consumers believe to be more valuable (ex ante) captures the entire market, quoting a price equal to the difference in the consumers' expected valuations.[14]

Comparing the equilibrium payoffs with uninformative demonstrations to the equilibrium payoffs when firm β provides demonstrations strategically gives the following result.

Proposition 5.2 *(Who benefits from demonstrations?). Compared to the case of no product demonstrations, allowing firm β to provide a demonstration strictly increases firm β's profit and strictly decreases consumer surplus. Firm α's profit may either increase or decrease when β supplies a demonstration.*

Therefore, the ability to design product demonstrations creates a transfer of surplus from consumers to firm β. The possibility that firm α may benefit from β's ability to offer demonstrations is reminiscent of the "puppy dog ploy" (Fudenberg and Tirole 1984), in which an established firm benefits by accommodating an entrant.

[13] Other subgame perfect equilibrium involve β setting a higher price, and then firm α setting a price just low enough to capture the entire market. Such alternative equilibria do not survive standard refinements of the equilibrium concept including trembling hand perfection.

[14] While the literature has established that sequential pricing can generate higher prices than simultaneous pricing, our model does not exhibit this feature. In case $\nu\theta > 1$, the equilibrium is unique and is identical to the one arising under simultaneous pricing. In case $\nu\theta < 1$ multiple equilibria are possible, but standard refinements select the one described in text, which is also identical to the one arising under simultaneous pricing.

6 REQUIRING FULLY INFORMATIVE DEMONSTRATIONS

In situations in which firm β is unable or unwilling to commit to a fully informative demonstration policy, such demonstrations may still arise if it is possible for government regulation to require extended return periods, informative trial environments or satisfaction guarantees. Such policies are often implemented with the goal of consumer protection. For example, Federal Communication Commission regulations provide for a two week full-refund cancellation of new mobile phone contracts with no early termination fees.[15] The guarantee allows a two week product demonstration to help address customer uncertainty about the phone and network. The expectation is that it would reduce (or even fully eliminate) customers' uncertainty about their product by offering them an extensive trial of the network and phone before committing to a long-term contract. In 2004, the Public Utilities Commission (PUC) of California passed a regulation requiring all cell phone companies to offer a thirty day return period. Although this regulation was later overturned after new appointments were made at the PUC in 2005, consumer advocacy groups continue to support the required thirty day return period.[16] In addition, fully informative demonstrations ensure that all consumers purchase the product that they value most, maximizing total (consumer plus producer) surplus.[17] Thus, a regulator interested in maximizing total surplus would require firm β to offer a fully informative demonstration. In this section, we explore the implications of this requirement. For purposes of this section, we imagine that firm β does not have commitment power to design its demonstration initially. Therefore, in the absence of this regulation, the game would proceed into the flexibility subgame.

A straightforward calculation reveals that requiring firm β to supply a fully informative demonstration always improves firm α profits and total surplus, and, as shown in Section 4, it increases firm β profits when (5) is satisfied. Thus, in the absence of other sources of commitment power for firm β, the requirement could allow firm β to make a profitable commitment to a fully informative demonstration design.

The requirement that β's demonstration is fully informative imposes a tradeoff for consumers: price competition is weaker, but, at the same time, fully informative demonstrations mean that consumers have better information about their value for the innovation and therefore make smarter purchase decisions. Thus, consumers benefit from commitment to fully informative demonstrations as long as the value of having better information about their valuations dominates the higher prices

[15] http://www.fcc.gov/encyclopedia/early-termination-fees

[16] Richard Holober, then Executive Director of the Consumer Federation of California argued that the required return period "would give consumers 30 days to check out a new phone and see if it works properly." In related setting, many states require the sellers of hearing aids to provide full refunds within 30 days. Despite a popular belief to the contrary, new and used car sales are not subject to any buyer's remorse law requiring that dealers provide a refund if the buyer changes his mind within a certain time period, although proposals for this type of legislation exist.

[17] Consult Proposition 4.5.

that they must pay. This is true whenever the value added by the innovation is sufficiently high.[18]

$$\nu > 4\theta. \tag{6}$$

Proposition 6.1 describes the impact of the requirement that firm β supply a fully informative demonstrations.

Proposition 6.1 *(Requiring fully informative demonstrations). Compared to the case of demonstration flexibility, requiring that firm β offers a fully informative demonstration (i) benefits firm β whenever (5) is satisfied, (ii) benefits consumers if and only if (6) is satisfied, (iii) always benefits firm α, and (iv) always maximizes total surplus*

Figure 1 plots conditions (5) and (6), illustrating the cases in which consumers benefit from commitment to fully informative demonstrations and the cases where firm β willingly commits to such demonstrations. Consumers only benefit from commitment to fully informative demonstrations in region A, while firm β is only willing to commit in region C. The regions do not overlap, implying that consumers never benefit from commitment to satisfaction guarantees or extended trial periods in situations in which the firm willingly offers them, and whenever the firm offers such fully informative demonstration policies, they make consumers worse off.

Figure 1: Benefits of fully informative demonstrations

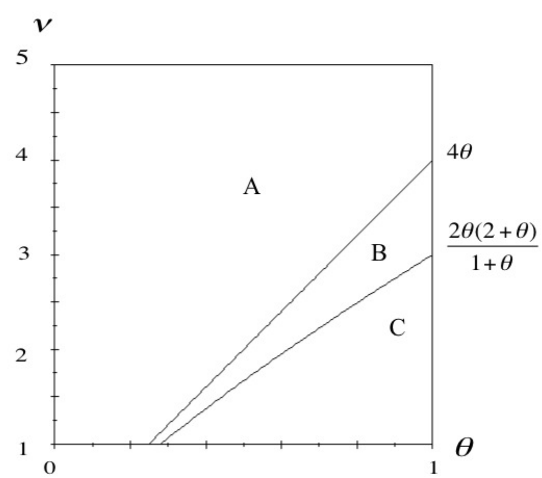

Figure 1 therefore implies the following corollary.

Corollary 6.2 *Whenever firm β prefers to commit to a fully informative demonstration, commitment hurts consumers. Commitment to fully informative demonstrations benefits consumers only*

[18]When ν is high, purchasing the right product is important for maximizing consumer surplus; at the same time, in the absence of the requirement that demonstrations are fully revealing, consumer surplus decreases with ν (consult Proposition 4.3),

in cases where the firm prefers not to commit.

The results of this section are summarized in the following table.

Table 1: Impact of requiring fully-informative demonstrations on payoffs

	Region A	Region B	Region C
Firm β profit	$-$	$-$	$+$
Consumer surplus	$+$	$-$	$-$
Firm α profit & social surplus	$+$	$+$	$+$

7 SIMULTANEOUS PRICE COMPETITION

Until now, the model considers sequential price competition between the firms. First, firm β sets a price when announcing the release of its new product. Second, firm α sets (or adjusts) the price for its established product in response to the new product release. In this section, we consider simultaneous price competition: firm α and firm β set prices at the same time—the model is otherwise unchanged. Although the sequential price model is more relevant for new product introduction (Kalra, Rajiv and Srinivasan 1998), the analysis in this section illustrates the effect of alternative assumptions regarding price competition on our results. Indeed, because simultaneous price competition is typically more severe than sequential price competition (Deneckere and Kovenock 1992, Kübler and Müller 2002), it is reasonable to expect that the anti-competitive consequences of product demonstrations are attenuated by simultaneous price competition, leaving consumers better off. However, this intuition is not necessarily borne out by our analysis: we demonstrate that simultaneous pricing may lead to worse outcomes for consumers than sequential pricing.

In the Appendix, we fully characterize all pure strategy equilibria of the game with simultaneous pricing. First, we consider the case of flexible demonstration design, ruling out "responsive" equilibria of the simultaneous pricing game in which firm α sets a price $p_\alpha < 1$. We then establish that when $p_\alpha = 1$ and firm β is flexible, then firm β is indifferent over all prices $p_\beta \in [\theta\nu, \nu]$. Next, we demonstrate that if and only if $\nu \geq 4\theta$ a price $p_\beta \in [\theta\nu, \nu]$ can be found for which $p_\alpha = 1$ is a best response. In this equilibrium, firm β expects to earn the monopoly profit, the highest possible profit that it could ever expect. Hence, whenever $\nu \geq 4\theta$, retaining flexibility dominates demonstration commitment for firm β. Therefore, whenever a pure strategy equilibrium arises under flexibility, retaining flexibility dominates initial commitment.

Lemma 7.1 *(Pure strategy equilibrium with simultaneous pricing). With simultaneous pricing, a pure strategy equilibrium of the demonstration and pricing game exists if and only if $\nu \geq 4\theta$. In every pure strategy equilibrium, $p_\alpha = 1$, π_α depends on p_β, $\pi_\beta = \theta\nu$, $CS = 0$, firm β retains flexibility and demonstrations are not fully informative.*

This equilibrium characterization is strongly reminiscent of the non-responsive equilibrium that arises in the game with sequential pricing whenever $\nu \geq 4\theta/(1-\theta^2)$ (recall Proposition 4.3). In both cases, $p_\alpha = 1$, $\pi_\beta = \nu\theta$, and $CS = 0$. Interestingly, the range of parameters in which this anticompetitive equilibrium exists is larger with simultaneous pricing than with sequential pricing. Thus, for $\nu \geq 4\theta/(1-\theta^2)$ consumer surplus is zero whether pricing is simultaneous or sequential. However, for $4\theta/(1-\theta^2) \geq \nu \geq 4\theta$, consumer surplus is positive in the equilibrium with sequential pricing (which is responsive) but is zero with simultaneous pricing. Instead of an equilibrium with stronger competition and higher consumer surplus, simultaneous pricing may lead to an equilibrium with weaker competition and a smaller consumer surplus. *Therefore, our results about the anticompetitive consequences of product demonstrations are strengthened (at least for a range of parameters) when pricing is simultaneous.* Furthermore, in this type of equilibrium with simultaneous pricing, the innovating firm prefers to retain flexibility in its demonstration design and always chooses a partially informative demonstration on the equilibrium path. Thus, with simultaneous pricing, the demonstration informativeness plays an even more significant strategic role than with sequential pricing. Finally, compared with uninformative demonstrations, firm β's profit is higher and consumer surplus is lower when β offers strategic product demonstrations. In fact, these effects are stronger with simultaneous pricing: in any pure strategy equilibrium, firm β's profit is weakly higher and consumer surplus is weakly lower than under sequential pricing.

To understand the implications of requiring fully informative demonstrations with simultaneous pricing, in the Appendix we solve for the equilibrium of the game when fully informative demonstrations are required and prices are set simultaneously. We show that in this case, pure strategy equilibria do not exist. We characterize the mixed strategy equilibrium of the pricing game, demonstrating that in equilibrium $\pi_\alpha = 1-\theta$, $\pi_\beta = \theta(\nu-\theta)$, and $0 < CS \leq \theta$. This characterization establishes the following proposition.

Proposition 7.2 *(Requiring fully revealing demos with simultaneous pricing). In the simultaneous pricing game with $\nu \geq 4\theta$, requiring fully informative demonstrations increases consumer surplus but reduces firm β's profit.*

Thus, we find a similar conflict of interest with simultaneous prices as we did with sequential prices: when $\nu \geq 4\theta$, requiring fully informative demonstrations benefits consumers, but the firm never voluntarily provides such demonstrations, even if it has the ability to commit to do so.

8 ENDOGENOUS INNOVATION STRATEGIES

The appeal of the innovative product may be measured along two dimensions: θ, which represents how widely appealing the innovation is, and ν, which represents how valuable the innovation is to those who find it appealing. Until now, the analysis has taken these measures of product appeal as exogenous. However, it is reasonable to assume that the firm may have at least some control over the appeal of its product.

In the Appendix, we generalize the model from Section 3, first to allow firm β to choose θ, and then to choose ν. The analysis shows that the main insights from earlier in the paper extend to these alternative settings. It also provides a handful of additional insights regarding the firm's preferences for releasing products with limited market appeal in order to segment the market and reduce price competition. In this section, we briefly summarize the main insights, and provide a more thorough analysis in the Appendix.

Limited product appeal

We first augment the game by allowing firm β to choose its product's appeal, θ, in the initial stage of the game.[19] We consider the case in which improving product appeal is *costless* to highlight the *strategic* determinants of product appeal. If the innovating firm prefers $\theta < 1$ when improving appeal (or even releasing a product that appeals to everyone) is costless, it does so in order to influence the behavior of the other firm, not to reduce its development costs. When the firm selects $\theta < 1$, it chooses to "limit" the appeal of its product.

This analysis produces a novel insight about how the presence of informative demonstrations can lead the firm to prefer releasing a product of limited appeal.

Proposition 8.1 *(Limited product appeal). In the absence of informative demonstrations, firm β releases a product that appeals to the entire market, setting $\theta = 1$. In the game with endogenous demonstrations, firm β prefers to release a product with limited market appeal (i.e. with $\theta < 1$) when $1 < \nu < 2$, and prefers to release a product that appeals to the entire market when $\nu \geq 2$.*

This proposition establishes that the ability to offer informative demonstrations is necessary for an innovating firm to limit the appeal of its product. In the absence of informative demonstrations, the innovating firm selects prefers a widely appealing product, with $\theta = 1$. The proposition also establishes that in the game with endogenous demonstrations, the firm prefers to release a product with limited market appeal whenever the value of that product is not too large. By releasing a product that does not appeal to everyone, firm β ensures that a large enough portion of the market is only interested in product α, which gives firm α an incentive to ignore the introduction of the new product and set a price to extract the greatest profits from its share of the market (rather than cut its price in an effort to retain the entire market). When the firm chooses $\theta < 1$, doing so helps it avoid price competition with the other firm.[20]

A few other insights from this analysis are worth mentioning. First, the firm prefers to release a product of limited appeal when ν is low enough, regardless of whether it must commit to a demonstration design up front, or it retains flexibility in demonstration design. Second, when both demonstrations and θ are endogenous demonstrations, the firm always prefers to commit to

[19] We assume that firm β chooses θ at the same time it chooses p_β. The results would not change if the firm chose θ and p_β sequentially.

[20] This result complements those of Bar-Isaac, Caruana and Cuñat (2012), who show that firms may prefer products with limited appeal emerges when consumer search costs decrease and are likely to generate extreme valuations for consumers.

a fully informative demonstration up front, and never prefers to retain flexibility in demonstration design. Third, when the value added of the innovation is not too large (i.e. when $1 < \nu < 3/2$), both consumer surplus and total surplus would be higher if the firm was unable to commit to a demonstration strategy up front. This contrasts with previous results focusing on the case of fixed θ, where total surplus is always largest with fully informative demonstrations. Fourth, with endogenous θ and $\nu < 2$, *total* surplus is lower with demonstrations than with no demonstrations, because demonstrations create incentives for a firm to limit the appeal of its product, reducing the number of consumers that benefit from new product release.

Investment in Value of Innovation

Next, we consider a case in which θ is exogenous, and firm β chooses ν, the value of the innovative product for those who find it appealing. When there are no costs associated with increasing ν, firm β strictly prefers to increase ν to the maximum possible value. We therefore focus on the case in which increasing ν is costly. Prior to price competition, firm β chooses ν at a cost $k\nu^2/2$. After the choice of ν, the game proceeds as it did in Section 4.

The analysis in the Appendix fully characterizes firm β's equilibrium choice of ν, the structure of which depends on the costs of investment k. In this framework, we show that consumer and total surplus are both higher when firm β commits to a fully informative demonstration policy than when the firm retains flexibility in demonstration design. The firm, however, is only willing to commit up front when both θ is large and k is moderate. This is similar to the main analysis where the firm commits to a fully informative demonstration policy when θ is sufficiently large, and consumers are better off if the firm committed in other situations as well. In both settings, total surplus is always maximized by commitment.

9 DISCUSSION AND IMPLICATIONS

We develop a game theoretic model in which a firm chooses a demonstration strategy, which determines how informed potential consumers are about the ability of a product to satisfy their individual needs. For example, a demonstration policy may determine how much time consumers have to interact with a new product, and may place restrictions on the environment in which they can try out the product prior to making a purchase decision.

Real world demonstration policies take many forms. The most informative demonstration policies are those that allowing consumers ample interaction with a product before they commit to a purchase decision. This is the case when firms offer extended trial periods and generous return policies. For example, MacKichan provides free 30 day trials of its Scientific Workplace software, Pantene offers a satisfaction guarantee on its shampoos and conditioners, Scotch Corp offers a satisfaction guarantee for its new Hair & Grease drain cleaner, and Clorox offers a similar satisfaction guarantee on their new Green Works line of environmentally friendly cleaning products. In each of these cases, the trial period or satisfaction guarantee allows a consumer to learn his value for a product before committing to the purchase.

Not all firms commit to such informative policies, rather opting to retain flexibility to control pre purchase interactions with their products until after prices have been established. Often the firms provide consumers with limited or even highly curated demonstration experiences. For example, Tesla Motors provides potential buyers with test drives accompanied by a dealer representative, while Bose and Apple offers hands on interactions with their products within the controlled environment of a Bose or Apple Store.

Our model gives a firm control over both the informativeness and timing of its demonstration strategy. The firm chooses whether to commit to a demonstration policy up front, before its competitor has an opportunity to set its price, or to retain flexibility to control consumer demonstrations at the point of sale, after prices are established. The firm also controls the informativeness of its demonstration policy. We give the firm full control over the informativeness of its demonstration, allowing it to choose fully information interactions, fully uninformative interactions, or anything in between.

When releasing a new product which offers some consumers significant value added over an established alternative, or when releasing a product that appeals to a small enough portion of consumers, our analysis shows that the firm is better off retaining the flexibility to control demonstrations after prices are established. In this case, equilibrium demonstrations are neither fully informative nor fully uninformative for consumers, resolving some but not all uncertainty about the ability of the new product to satisfy their individual needs. This result is reminiscent of Apple's sale of new products, including the iPod, iPhone and iPad, which offered consumers significant value added over the established alternatives, including the Sony Diskman, flip phone or Blackberry, and netbooks. Our analysis suggests that Apple would prefer to retain flexible control over pre purchase demonstrations, which is consistent with Apple offering consumers hands on interactions with their products in the highly curated Apple Store environment.

Alternatively, when releasing a new product that offers only a small improvement over existing products, but appeals to a large portion of consumers, our analysis shows that the firm should commit to provide fully informative demonstrations. This result is consistent with Sprint and HTC's 2010 release of the Evo 4G. The Evo was seen as the first Android phone that may be more appealing than the iPhone (which by then was already established) to a significant portion of consumers. However, although the new phone provided a larger display and faster processor, these improvements represented relatively small increases in value added for consumers. Our analysis suggests that Sprint and HTC may have benefited from committing to fully informative demonstrations, which they essentially did by offering new customers a 30 day money back satisfaction guarantee.

The earlier mentioned examples are also consistent with our results. For example, the Tesla Model S may offer high value added compared to alternative vehicles in its market segment, in which case our analysis predicts controlled. On the other hand, high end personal hygiene products and innovative household cleaning supplies may be appealing to a large portion of a market, but offer relatively low value added over competitors. Our analysis suggests that such products should be offered with highly informative demonstration policies, such as satisfaction guarantees. Countless examples abound.

The analysis offers a number of implications for both management strategy and consumer protection. For management, the analysis suggests the following:

- If a firm chooses a demonstration policy after prices are established, it should provide demonstrations which resolve some but not all consumer uncertainty about its product. By manipulating the informativeness of its demonstration ex post, it can maximize its market share given prices. (*Lemma 4.2 and Proposition 4.3*)

- If a firm commits to a demonstration policy up front, it should commit to the most informative feasible demonstration, perhaps by offering a generous return policy, satisfaction guarantee or trial period. Committing to such a policy most effectively differentiates its new product from the established competition, providing the greatest benefits in terms of decreased price competition. (*Lemma 4.5*)

- The innovating firm should commit to a demonstration policy up front when its product is widely appealing but offers relatively low value added. In this case, the benefits of reduced price competition dominate the loss in market share that accompany commitment to a fully informative demonstration for the innovative firm. (*Proposition 4.6*)

- For products that appeal to a narrow portion of the market, or for products that offer a large increase in value over the existing product, the innovative firm should retain flexibility in its demonstration design until after prices are established. (*Proposition 4.6*)

- The established firm, always benefits from the other firm being committed to a fully informative demonstration policy (e.g. satisfaction guarantee). In our environment, the established firm should push for regulation or legislation requiring fully informative demonstrations, even in cases where the innovative firm prefers not to provide them. (*Proposition 4.6*)

- From the perspective of the innovating firm, the value added and the market appeal of the innovation are complementary attributes for increasing profit. When value added is high, the firm is best off when its product is also widely appealing. When value added is low, the firm is best off when its product appeals to only a portion of the market. (*Proposition 8.1*)

For consumer protection and market regulation, the analysis suggests the following:

- One may think that consumers would benefit from exposure to a more informative demonstration prior to purchase. This view ignores the impact that additional consumer information has on price competition. We show that consumers may be made worse off by exposure to more informative product demonstrations. (*Lemma 4.4 and Proposition 5.2*)

- Whenever the innovating firm willingly commits to a satisfaction guarantee or other fully informative demonstration policy, such fully informative policies decrease consumer surplus. (*Proposition 4.6*)

- In cases where the firm does prefers not to commit to a fully informative demonstration policy, consumer surplus may be improved by a regulation requiring the firm to offer such demonstrations, though not necessarily. This type of regulation is beneficial for consumers when the product offers sufficiently high value added or sufficiently low market appeal compared to the established alternative. Otherwise, such regulation may have the opposite effect as intended, decreasing consumer surplus. (*Table 1*)
- Although requiring fully informative demonstrations may hurt consumers, it always improves total (consumer plus producer) surplus. (*Table 1*)

Our model is a better representation of some market settings than others. We assume customer uncertainty about only one of the products, and therefore only one firm can affect consumer beliefs about their product by offering demonstrations. Although we believe the assumptions provide a reasonable representation of many markets, they certainly do not match all markets in which information provision can take place. Future research may extend our results to incorporate multiple product releases, either simultaneously or over time. Additionally, firms could have private information about the appeal of their product. Consumers would therefore learn about their values by observing both the realization of the demonstration (i.e., their impression) and the design of the demonstration (e.g., how much access to the product the firm allows). The design of the demonstration would play a signaling role, absent in our analysis. We leave these interesting issues for future research.

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A APPENDIX

A.1 ANALYSIS WITH SEQUENTIAL PRICING

Lemma 4.1. Description of when a consumer purchases from firm β.

Proof. Consumer i strictly prefers to purchase product β over product α if and only if $\mu_i - p_\beta > 1 - p_\alpha$. The assumption that an indifferent consumer purchases β implies the condition $\mu_i - p_\beta \geq 1 - p_\alpha$. Rearranging gives the condition $\mu_i \geq 1 - p_\alpha + p_\beta$, where the right hand side of this inequality is $\bar{\mu}(p_\alpha, p_\beta)$; therefore, consumer i prefers product β over product α when $\mu_i \geq \bar{\mu}$.

Finally, we must establish that the consumer prefers to buy β rather than not buy either product when this inequality is satisfied. Because we focus on equilibria in which $p_\alpha \leq 1$, it follows that $\mu_i \geq 1 - p_\alpha + p_\beta \geq p_\beta$. Therefore, any μ_i satisfying $\mu_i \geq \bar{\mu}$ also satisfies $\mu_i \geq p_\beta$. Thus, when $\mu_i \geq \bar{\mu}$, consumer i prefers purchasing from β than either not purchasing or purchasing from the other firm. ■

Lemma 4.2. Description of the sequentially rational product demonstration strategy, when firm β chooses d after prices have been established.

Proof. Consumers either experience favorable or bad demonstration realizations. All consumers who experience bad realizations will purchase from firm α if and only if $p_\alpha \leq 1$. All consumers who experience good realizations will purchase from firm β if and only if (1) is satisfied.

- When $\nu < \bar{\mu}$, no choice of demonstration $d \in [0, 1]$ satisfies (1), and thus firm β sells to no one.
- When $\theta\nu < \bar{\mu} \leq \nu$, firm β's optimal choice of d, as determined by (2), is feasible, and therefore, firm β sets $d = d^*$ and sells to the fraction $1-(1-\theta)d^*$ of consumers who experience a favorable demonstration realization.
- When $\bar{\mu} \leq \theta\nu$, every choice of demonstration $d \in [0, 1]$ results in firm β selling the portion of the market with favorable demonstration realizations. Since prices are already established, firm β's optimal demonstration strategy in this case maximizes the portion of the population that has a favorable demonstration. Therefore, firm β sets $d = 0$, ensuring that no one receives a bad impression of the product from the demonstration.

The corresponding values of π_α, π_β and CS are calculated by plugging the above values of d into the corresponding expressions. ■

Proposition 4.3. Description of equilibrium outcomes when firm β chooses d after prices have been established.

Proof. Solving for the equilibrium outcome using backwards induction, we first determine firm α's price. Then, we consider the pricing decision of firm β in the initial stage of the game.

Firm α's pricing strategy. Firm α's pricing strategy must set a price p_α which is a best response (i.e. maximizes π_α) to p_β, given the it anticipates that firm β will respond to the pricing decision by setting a sequentially rational demonstration d in the next stage.

$$\pi_\alpha(p_\alpha, p_\beta) = \begin{cases} p_\alpha & \text{if} \quad p_\alpha < p_\beta + 1 - \nu \\ (1 - \frac{\nu\theta}{\bar{\mu}(p_\alpha, p_\beta)})p_\alpha & \text{if} \quad p_\beta + 1 - \nu \leq p_\alpha \leq \min\{p_\beta + 1 - \nu\theta, 1\} \\ 0 & \text{if} \quad p_\alpha > \min\{p_\beta + 1 - \nu\theta, 1\} \end{cases}$$

Observe first that if $p_\beta + 1 - \nu\theta < 0 \Leftrightarrow p_\beta < \nu\theta - 1$ then α cannot earn non-zero profit with any positive price. In this case, firm α is indifferent over all prices.

Ignoring the restriction that $p_\alpha \geq 0$, the function $\pi_\alpha(p_\alpha, p_\beta)$ has three distinct pieces. Below threshold $p_\beta + 1 - \nu$ it is a linear function. At $p_\beta + 1 - \nu$ the function has a downward discontinuity jumping to value $(1 - \nu\theta)p_\alpha$, and then follows a "hump-shaped" function $(1 - \nu\theta/\bar{\mu})p_\alpha$. At a second threshold the payoff could have a downward discontinuity to zero (if $p_\beta + 1 - \nu\theta > 1$), or could become zero at $p_\beta + 1 - \nu\theta$ and remain there for all higher values. This implies that only three possibilities exist for firm α best response. The first is market capture, which would be a price along the linear part of the payoff function. The second is optimal defense, which is the top of the "hump" (as long as it is feasible). The third option is "unresponsive pricing" at the maximum price that α could charge and still make sales.

Notice that whenever $p_\beta + 1 - \nu\theta < 1$, selecting $p_\alpha = 1$ gives payoff of $1 - \nu\theta/p_\beta$ which in this case is negative, and whenever $p_\beta + 1 - \nu\theta > 1$ choosing $p_\alpha = 1$ gives a strictly positive payoff. Meanwhile, choosing $p_\alpha = p_\beta + 1 - \nu\theta$ always gives payoff zero. Thus whenever $\min\{p_\beta + 1 - \nu\theta, 1\} = p_\beta + 1 - \nu\theta$ the payoff at $p_\alpha = p_\beta + 1 - \nu\theta$ is higher than the payoff at $p_\alpha = 1$ and vice versa.

By adopting a market capture strategy, firm α can guarantee itself a payoff arbitrarily close to $p_\beta + 1 - \nu$.

Next, consider the value of p_α that maximizes $(1 - \frac{\nu\theta}{\bar{\mu}(p_\alpha, p_\beta)})p_\alpha$ ignoring constraints on the interval. First and second order conditions imply that the maximizer is given by

$$p_\alpha^D = 1 + p_\beta - \sqrt{\nu\theta(1 + p_\beta)} \tag{7}$$

and the maximized payoff is given by $\pi^D = \nu\theta + 1 + p_\beta - 2\sqrt{\nu\theta(1 + p_\beta)}$. Note that $p_\beta > \nu\theta - 1 \Rightarrow p_\alpha^D, \pi^D > 0$ and $p_\alpha^D < p_\beta + 1 - \nu\theta$. Thus p_α^D is firm α's best response whenever

$$p_\alpha^D \leq 1, \quad \text{and} \tag{8}$$

$$\pi^D \geq p_\beta + 1 - \nu. \tag{9}$$

The first condition requires that the maximizer p_α^D is inside the admissible interval and the second condition requires that optimal defense is preferred to market capture. For $p_\beta \geq 0$ condition (8) reduces to

$$p_\beta \leq \frac{1}{2}(\nu\theta + \sqrt{(\nu\theta)^2 + 4\nu\theta})$$

Condition (9) requires that

$$\nu\theta + 1 + p_\beta - 2\sqrt{\nu\theta(1+p_\beta)} \geq p_\beta + 1 - \nu$$

which is equivalent to

$$p_\beta \leq \frac{(1+\theta)^2\nu}{4\theta} - 1$$

Therefore, if

$$p_\beta \leq \min\{\frac{(1+\theta)^2\nu}{4\theta} - 1, \frac{1}{2}(\nu\theta + \sqrt{(\nu\theta)^2 + 4\nu\theta})\}$$

then firm α's best response to p_B is to set $p_\alpha = p_\alpha^D$. The first term inside $\min\{\cdot\}$ is greater than the second term if and only if

$$\nu \geq \frac{4\theta}{1-\theta^2}$$

a condition that is always satisfied when $\theta \leq \sqrt{5} - 2$, and satisfied when ν is sufficiently large for $\theta > \sqrt{5} - 2$. Hence, firm α's best response is to optimally defend, $p_\alpha = p_\alpha^D$, if either of the following sets of conditions hold

$$\nu \geq \frac{4\theta}{1-\theta^2} \quad \text{and} \quad \nu\theta - v_\alpha < p_\beta \leq \frac{1}{2}\left(\nu\theta + \sqrt{(\nu\theta)^2 + 4\nu\theta}\right) \tag{10}$$

$$\nu < \frac{4\theta}{1-\theta^2} \quad \text{and} \quad \nu\theta - v_\alpha < p_\beta \leq \frac{(1+\theta)^2\nu}{4\theta} - 1. \tag{11}$$

Next, suppose that condition (8) does not hold, so that firm α optimal defensive price is infeasible, because it is greater than $v_\alpha = 1$. This means that the payoff function is increasing on $[p_\beta + 1 - \nu, 1]$, and therefore that the optimal price in this interval is $p_\alpha = 1$. Choosing this (unresponsive) price gives payoff $1 - \frac{\nu\theta}{p_\beta}$. For this approach to dominate full capture it must be that:

$$1 - \frac{\nu\theta}{p_\beta} \geq p_\beta + 1 - \nu$$

which implies that

$$p_\beta \leq \frac{1}{2}(\nu + \sqrt{\nu^2 - 4\nu\theta}).$$

Hence, for unresponsive pricing to be the best response it must be that

$$\frac{1}{2}(\nu\theta + \sqrt{(\nu\theta)^2 + 4\nu\theta}) < p_\beta \leq \frac{1}{2}(\nu + \sqrt{\nu^2 - 4\nu\theta}). \tag{12}$$

Observe also that

$$\frac{1}{2}(\nu\theta + \sqrt{(\nu\theta)^2 + 4\nu\theta}) \leq \frac{1}{2}(\nu + \sqrt{\nu^2 - 4\nu\theta}) \Rightarrow \nu \geq \frac{4\theta}{1-\theta^2}$$

This condition is necessary for $p_\alpha = 1$ to be a best response, and also implies that the upper bound,

$\frac{1}{2}(\nu+\sqrt{\nu^2-4\nu\theta})$ is a real number. The only other possibility for a best response is market capture; hence for any other combination of model parameters, market capture is the best response.

To summarize, firm α's equilibrium pricing strategy: When $p_\beta \leq \nu\theta - 1$, firm α is indifferent between all p_α, and therefore all are consistent. When $p_\beta > \nu\theta - 1$, firm α's sequentially rational pricing strategy involves

- Unresponsive pricing, $p_\alpha = 1$, if $\nu \geq 4\theta/(1-\theta^2)$ and (12).
- Optimal defensive pricing with p_α given by (7), if either (10) or (11).
- Full market capture, setting p_α just below $p_\beta + 1 - \nu$ in all other cases.

Firm β's pricing strategy. When setting a price in the first stage of the game, the firm must anticipate sequentially rational firm α pricing and its own sequentially rational demonstration strategy in the next stages. Firm β profit function is:

$$\pi_\beta(p_\beta) = \begin{cases} p_\beta & \text{if} \quad p_\beta \leq \nu\theta - 1 \\ \nu\theta & \text{if} \quad BR_\alpha(p_\beta) = 1 \\ \frac{p_\beta\sqrt{\nu\theta}}{\sqrt{1+p_\beta}} & \text{if} \quad BR_\alpha(p_\beta) = p_\alpha^D \\ 0 & \text{if} \quad BR_\alpha(p_\beta) = p_\alpha^{mc} \end{cases}$$

where BR_α denotes firm $\alpha's$ best response price to p_β, as determined by the derivation of firm α's equilibrium pricing strategy above.

Consider first the case of $\nu < (4\theta)/(1-\theta^2)$. In this case, firm α's above derived equilibrium pricing strategy implies that the only possible best responses for firm α are market capture or defensive pricing. If firm α does market capture, then $\pi_\beta = 0$, which could never be optimal. As long as p_β induces $BR_\alpha(p_\beta) = p_\alpha^D$, firm β payoff is strictly increasing in p_β. Thus, if firm β were to induce optimal defense as a best response, it is best to choose the largest value of p_β which does so. From firm α's above derived equilibrium pricing strategy, the largest price which induces defense as a best response is $p_\beta = (1+\theta)^2\nu/(4\theta) - 1$. If β sets this price it expects profit $((1+\theta)^2\nu - 4\theta)/(2(1+\theta))$. Firm β could also capture the market optimally by setting $p_\beta = \nu\theta - 1$. A simple calculation shows that this approach is worse than inducing α to defend:

$$\frac{(1+\theta)^2\nu - 4\theta}{2(1+\theta)} - (\nu\theta - 1) = \frac{1-\theta}{2(1+\theta)}((1+\theta)\nu + 2) > 0$$

Hence, if $\nu < (4\theta)/(1-\theta^2)$, then the optimal price for β to charge is

$$p_\beta = \frac{(1+\theta)^2\nu}{4\theta} - 1. \tag{13}$$

Next, consider the alternative case $\nu \geq (4\theta)/(1-\theta^2)$. In this case, an interval of prices for firm β exists such that α's best response is $p_\alpha = 1$. Any such price gives payoff $\nu\theta$. Any lower

p_β induces defense as a best response. However, the payoff function is increasing over prices that induce defense. Furthermore, the payoff function is continuous at $p_\beta = (1/2)(\nu\theta + \sqrt{(\nu\theta)^2 + 4\nu\theta})$, as this price also generates an expected π_β of $\nu\theta$. Thus, inducing firm α to best respond with $p_\alpha = 1$ is preferred to inducing a defensive response. Obviously $\nu\theta > \nu\theta - 1$, and therefore this approach is also preferred to market capture. Hence, when $\nu \geq (4\theta)/(1-\theta^2)$ any price for which α's best response involves $p_\alpha = 1$ is optimal.

To summarize, firm β's equilibrium price depends on parameters ν and θ:

- If $\nu \geq 4\theta/(1-\theta^2)$, firm β chooses any p_β that induces a non responsive pricing strategy $p_\alpha = 1$ as a best response. That is, firm β chooses p_β to satisfy (12).
- If $\nu < 4\theta/(1-\theta^2)$, firm β chooses p_β according to (13), which induces a defensive pricing strategy by firm α.

The complete characterization of equilibrium outcomes under flexible pricing follows immediately from these results and the earlier Lemmas. ■

Lemma 4.4. Describes equilibrium outcome under exogenous commitment to demonstration d_c.
Proof. Follows from analysis in the body of the paper. ■

Proposition 4.5 Shows that firm β prefers $d_c = 1$ to any other commitment.
Proof. Follows immediately from the fact that π_β from Lemma 4.4 is strictly increasing in d_c, and that $d_c = 1$ satisfies (4). ■

Proposition 4.6. Describes firm β's equilibrium decision of whether to commit to a demonstration strategy in the initial stage or to retain flexibility in demonstration design.
Proof. We have already established that firm β prefers commitment to a fully informative demonstration strategy to any other level of commitment. The firm prefers such commitment to retaining flexibility in demonstration design only if its expected profits from commitment (which equal $\pi_\beta = \theta(\nu - \theta)$) are at least as large as its expected profits from not committing and retaining flexibility in demonstration design. Retaining flexibility results in expected profits of $\pi_\beta = \nu\theta$ when $\nu \geq 4\theta/(1-\theta^2)$ and $\pi_\beta = (1+\theta)\nu/2 - 2\theta/(1+\theta)$ otherwise.

First, it is clear that

$$\nu\theta > \theta(\nu - \theta) = \nu\theta - \theta^2,$$

and therefore the firm always prefers flexibility when ν is large. Second, compare the payoffs for the case of smaller nu. Here, commitment is preferred if and only if

$$\nu\theta > \frac{(1+\theta)\nu}{2} - \frac{2\theta}{1+\theta}.$$

Rearranging this inequality gives condition (5) from the body of the paper. The rest of the proposition follows from the equilibrium requirement that play be sequentially rational after the firm decides whether or not to commit, and therefore follows Propositions 4.3 and 4.5 in the later stages. ■

Proposition 5.1. Shows that with fixed prices, more information is good for consumers and bad for firm β profits.

Proof. Consider the case in which p_α, p_β and d_c are fixed, and d_c satisfies (1).

$$\pi_\alpha = (1-\theta)d_c p_\alpha,$$

which is strictly increasing in d_c.

$$\pi_\beta = (1-(1-\theta)d_c)p_\beta,$$

which is strictly decreasing in d_c.

$$CS = \theta(\nu - p_\beta) + (1-\theta)(1-d_c)(-p_\beta) + (1-\theta)d_c(1-p_\alpha),$$

which is strictly increasing in d_c, given the constraints on the parameters and prices.

When d_c does not satisfy (1), all consumers, including those that experience favorable demonstrations, purchase from firm α. In this case, $\pi_\beta = 0$ and $CS = 1 - p_\alpha$. Whenever d_c satisfies (1), CS and π_β are both larger than when (1) is not satisfied. ■

Proposition 5.2. Compares payoffs in the case where there are no demonstrations with payoffs when the firm controls demonstration informativeness.

Proof. In commitment equilibrium of the endogenous demonstration game, consumer surplus (CS) is θ^2, which is strictly less than consumer surplus in the case of no demonstrations. In the non-responsive equilibrium with flexible demo design, CS is zero, clearly less than consumer surplus with no demonstrations. In the responsive equilibrium with flexible demo design, consumers surplus is $1-(1-\theta^2)\nu/(4\theta)$, which is clearly less than CS under no demonstrations in the case of $\nu\theta \geq 1$ (in which case $CS = 1$). For the case of $\nu\theta < 1$, CS is greater under flexible demo design than under no demos if

$$1 - \frac{(1-\theta^2)\nu}{4\theta} > \theta\nu \Rightarrow \nu < \frac{4\theta}{1+3\theta^2}$$

This implies a region of the parameter space in which endogenous flexible demonstrations result in higher CS compared to the game without demonstrations. However, $\nu < 4\theta/(1+3\theta^2)$ implies that the condition $\nu < 2\theta(2+\theta)/(1+\theta)$ is satisfied, and therefore in the game with endogenous demonstration design firm β chooses to commit to a demonstration policy up front, rather than retain flexibility. Consumers are always worse off under endogenous demonstrations and commitment than under no demos. For all parameter values under which the firm elects to retain flexibility in the endogenous demo game, consumers are also worse off under endogenous, flexible demos than under no demos. Thus, in equilibrium, consumers are worse off under endogenous demos than under no demos.

Next we show that firm β profit is higher with endogenous demos compared to no demos. If

$\theta\nu < 1$ then $\pi_\beta = 0$ under no demo, and is clearly higher under endogenous demos. If $\theta\nu > 1$ then π_β profit is $\theta\nu - 1$ under no demo. This is the same payoff as would arise if firm β chose to capture the market (see proof of Proposition 4.3). As capturing the market is never firm β's optimal strategy, it must be that π_β is higher in both the responsive and non-responsive equilibria of the endogenous demo game than with no demos. Finally, $\pi_\beta = \theta(\nu - \theta)$ when it commits to a fully informative demo up front. It is straightforward to show that $\theta(\nu - \theta) > \theta\nu - 1$, and therefore, π_β is also higher in the commitment equilibrium of the endogenous demo game than with no demos. To see that α may benefit from demos, note that whenever $\nu\theta > 1$, in the absence of demonstrations α's profit is zero. Meanwhile, in every possible equilibrium structure, α's profit is positive if demonstrations are allowed. To see that α may be harmed by demonstrations, note that when $\nu\theta < 1$ firm α profit without demonstrations is $1 - \nu\theta$. Meanwhile, in the region $\nu > 4\theta/(1-\theta^2)$ the non-responsive equilibrium obtains, generating profit $\pi_\alpha = 1 - \nu\theta/p_\beta$. The highest profit for α is for $p_\beta^H = \frac{1}{2}(\nu\theta + \sqrt{\nu^2\theta^2 + 4\nu\theta})$. Profit with demonstrations is lower whenever $p_\beta^H < 1$, which is equivalent to $\nu\theta < 1/2$. Hence, a region with $1/2 < \nu\theta < 1$ and $\nu > 4\theta/91 - \theta^2)$ in which α is made worse off by demonstrations. ■

Proposition 6.1. Determines when the players each benefit from fully informative demonstrations compared to flexible demonstrations.

Proof. The calculation for firm β follows immediately from Proposition 4.6.

Firm α earns $\pi_\alpha = 1 - \theta$ under commitment to fully informative demos, and earns payoffs according to Proposition 4.3 under flexibility. To show that firm α always benefits from commitment to fully informative demos, we first show that it benefits in the case of the responsive equilibrium under flexibility, which requires $\nu < 4\theta/(1-\theta^2)$. For firm α to prefer commitment, it must be that

$$\frac{(1-\theta)^2\nu}{4\theta} < 1 - \theta \iff \nu < \frac{4\theta}{1-\theta}.$$

This condition is always satisfied given the requirement that $\nu < 4\theta/(1-\theta^2)$, since

$$\frac{4\theta}{1-\theta^2} < \frac{4\theta}{1-\theta} \iff \frac{1}{1+\theta} < 1 \iff 0 < \theta.$$

The non responsive equilibrium under flexibility arises when $\nu \geq 4\theta/(1-\theta^2)$. Here, given the focus on the Pareto optimal equilibrium,

$$\pi_\alpha = 1 - \frac{2\nu\theta}{\nu\theta + \sqrt{\nu^2\theta^2 + 4\nu\theta}}.$$

This is less than under fully informative demos, where $\pi_\alpha = 1 - \theta$. To see this,

$$1 - \frac{2\nu\theta}{\nu\theta + \sqrt{\nu^2\theta^2 + 4\nu\theta}} < 1 - \theta \iff \sqrt{\nu^2\theta^2 + 4\nu\theta} < \nu(2-\theta) \iff$$

$$\nu^2\theta^2 + 4\nu\theta < \nu^2(2-\theta)^2 \iff \nu > \frac{\theta}{1-\theta}.$$

This condition is always satisfied given the requirement that $\nu \geq 4\theta/(1-\theta^2)$, since

$$\frac{\theta}{1-\theta} < \frac{4\theta}{1-\theta^2} \iff 1+\theta < 4 \iff \theta < 3.$$

Thus, firm α always earns higher expected profits under commitment than under flexibility.

Consumers earn $CS = 0$ in the non responsive equilibrium of the flexible demo game, and are therefore made better off with commitment to fully informative demos, under which they earn θ^2. They prefer commitment to the responsive equilibrium of the flexible demo game when:

$$1 - \frac{1-\theta^2}{4\theta}\nu < \theta^2 \iff 1-\theta^2 < \frac{1-\theta^2}{4\theta}\nu \iff 4\theta < \nu.$$

Since $4\theta < 4\theta/(1-\theta^2)$ for all θ, it implies that whenever $\nu < 4\theta$, the equilibrium of the flexible demo subgame involves the responsive equilibrium, and therefore CS is lower under commitment than flexibility if and only if $\nu < 4\theta$. CS is higher under commitment whenever $\nu \geq 4\theta$. ■

Corollary 6.2. Shows that consumers are not made better off by commitment in cases when the firm is willing to commit.

Proof. Follows immediately from the fact that Regions A and C do not overlap in Figure 1. For any θ,

$$4\theta > \frac{2\theta(2+\theta)}{1+\theta} \iff 2+2\theta > 2+\theta \iff \theta > 0.$$

Thus $\nu > 4\theta$ implies $\nu > 2\theta(2+\theta)/(1+\theta)$. ■

A.2 MODEL WITH SIMULTANEOUS PRICE COMPETITION

Flexibility in demonstration design

The equilibrium of the demonstration subgame is the same as in the model with sequential price competition. From Lemma 4.2, we know that the equilibrium demonstration design depends on the value of $\bar{\mu} \equiv 1 - p_\alpha + p_\beta$ relative to ν and $\nu\theta$. When $\nu < \bar{\mu}$, there does not exist a demonstration design such that β captures any of the market and in equilibrium $\pi_\alpha = p_\alpha$ and $\pi_\beta = 0$. When $\nu\theta < \bar{\mu} \leq \nu$, firm β will choose $d = d^*$, giving $\pi_\alpha = (1-\nu\theta/\bar{\mu})p_\alpha$ and $\pi_\beta = (\nu\theta/\bar{\mu})p_\beta$. When $\bar{\mu} \leq \nu\theta$, β chooses $d = 0$, giving $\pi_\alpha = 0$ and $\pi_\beta = p_\beta$.

During price competition, it will never be a best response for firm β to choose a price that leads to $\nu < \bar{\mu}$. Firm β would have an incentive to deviate from doing so to instead choose a p_β such that one of the two other cases is reached, and $p_\beta > 0$. Because $\nu > 1$, this is always feasible for firm β, even when $p_\alpha = 0$. This rules out the possibility of an equilibrium in which $\nu < \bar{\mu}$.

Similarly, we can rule out the possibility of an equilibrium in which $\bar{\mu} \leq \nu\theta$. If we are in this case, then firm α has an incentive to lower its price if doing so results in $\nu\theta < \bar{\mu}$. This is only not possible if both $\nu\theta > 1$ and $1 \leq \nu\theta - p_\beta$. For β, the profit maximizing p_β such that $\bar{\mu} \leq \nu\theta$ is

$p_\beta = \nu\theta + p_\alpha - 1$, which is greater than $\nu\theta - 1$ except when $p_\alpha = 0$. Therefore, the only possibility under which $\bar{\mu} \leq \nu\theta$ involves $p_\alpha = 0$ and $p_\beta = \nu\theta - 1$, in which case $\pi_\beta = \nu\theta - 1$. However, if this is the case, firm β could alternatively set $p_\beta = \nu - 1$ followed by $d = 1$, which gives $\pi_\beta = \nu\theta - \theta$. Since $\nu\theta - \theta > \nu\theta - 1$, it is never a best response to $p_\alpha = 0$ to set $p_\beta = \nu\theta - 1$, eliminating this possibility in equilibrium.

Thus, in any pure strategy equilibrium, firm prices must be such that

$$\nu\theta < \bar{\mu}(p_\alpha, p_\beta) \leq \nu. \tag{14}$$

Next, we show that in any pure strategy equilibrium, $p_\alpha = 1$. To do so, consider profit of the two firms when (14) is met.

$$u_\alpha = (1 - \frac{\theta\nu}{1 - p_\alpha + p_\beta})p_\alpha \quad \text{and} \quad u_\beta = \frac{\theta\nu}{1 - p_\alpha + p_\beta}p_\beta.$$

Derivates with respect to the relevant variables are

$$\frac{\partial u_\alpha}{\partial p_\alpha} = 1 - \frac{\theta\nu(1 + p_\beta)}{(1 - p_\alpha + p_\beta)^2} \quad \text{and} \quad \frac{\partial u_\beta}{\partial p_\beta} = \frac{\theta\nu(1 - p_\alpha)}{(1 - p_\alpha + p_\beta)^2}.$$

For any $p_\alpha < 1$, $\partial u_\beta / \partial p_\beta > 0$. This means that conditional on (14), firm β's best response to any $p_\alpha < 1$ involves setting the highest value of p_β such that (14) holds (i.e. $p_\beta = \nu - 1 + p_\alpha$) followed by a fully informative demonstration policy $d = 1$. Such a strategy gives $\pi_\beta = \theta(\nu - 1 + p_\alpha)$. This is the best response for β compared to any other p_β if it offers a higher payoff compared to setting a low enough price that β captures the entire market (if such a price is even feasible). This full market capture alternative involves $p_\beta = \nu\theta - 1 + p_\alpha$ followed by $d = 0$, and gives firm β profits $\pi_\beta = \nu\theta - 1 + p_\alpha$. Therefore, firm β's best response to p_α involves $p_\beta = \nu - 1 + p_\alpha$ and $d = 1$ when $\theta(\nu - 1 + p_\alpha) \geq \nu\theta - 1 + p_\alpha$; a condition that always holds.

Thus, firm β's best response to any $p_\alpha < 1$ involves $p_\beta = \nu - 1 + p_\alpha$. Such a choice of p_β by firm β gives firm α a strict incentive to deviate to a marginally lower price. If firm α sets its price just marginally below the p_α in $p_\beta = \nu - 1 + p_\alpha$, then there exists no demonstration policy that firm β can provide in the second stage which will entice even those consumers with high value for firm β's product to buy it. A marginal decrease in firm α's price allows it to capture the entire market. The only time such a deviation is not possible for firm α is when $p_\alpha = 0$. Therefore, there exists no p_α, p_β combination such that $0 < p_\alpha < 1$ and p_α and p_β are best responses to each other. This rules out the existence of pure strategy equilibrium in which $0 < p_\alpha < 1$.

Next, we rule out the possibility that $p_\alpha = 0$ in equilibrium. If this is the case, then firm β's best response involves $p_\beta = \nu - 1$; that is, we already established that when $p_\alpha < 1$, firm β prefers to offer fully informative trials and set a price that fully extracts the surplus of those with high value for its product. Given β's best response strategy, firm α could earn higher profits by increasing its price. To see this, evaluate $\partial u_\alpha / \partial p_\alpha$ at $p_\beta = \nu - 1$. This gives $\partial u_\alpha / \partial p_\alpha = 1 - \theta\nu^2 / (\nu - p_\alpha)^2$, which is strictly positive at $p_\alpha = 0$. This rules out the possibility of a pure strategy equilibrium in which

$p_\alpha = 0$.

The only remaining possibility involves pure strategy equilibria in which $p_\alpha = 1$. When $p_\alpha = 1$, $\partial u_\beta / \partial p_\beta = 0$ for all values of p_β. This means that β is indifferent between any p_β such that (14) holds. Each value gives $u_\beta = \theta\nu$. Notice that this is the same expected payoff that β would receive if it set $p_\beta = \nu\theta - 1 + p_\alpha = \nu\theta$, which allows it to capture the entire market. Therefore, there never exists an incentive for β to deviate from any $p_\beta \in [\nu\theta, \nu]$, as each gives $\pi_\beta = \nu\theta$.

There must also not exist an incentive for firm α to deviate to a lower value of p_α. This requires that: (1) firm α doesn't prefer a marginally lower p_α, which requires $\partial u_\alpha / \partial u_\beta \geq 0$ when evaluated at $p_\alpha = 1$; and (2) firm α doesn't prefer a deviation to a low enough price that it captures the entire market.

It is the case that $\partial u_\alpha / \partial p_\alpha \geq 0$ when $p_\alpha = 1$ when

$$1 - \frac{\theta\nu(1 + p_\beta)}{p_\beta^2} \geq 0.$$

Solving this for p_β gives the requirement

$$\frac{1}{2}(\theta\nu - \sqrt{(\theta\nu)^2 + 4\theta\nu}) \leq p_\beta \leq \frac{1}{2}(\theta\nu + \sqrt{(\theta\nu)^2 + 4\theta\nu}). \tag{15}$$

We have already established that in any pure strategy equilibrium, p_β must satisfy $\theta\nu < p_\beta \leq \nu$. The lower bound in (15) is lower than $\theta\nu$. Value ν is at least as great as the upper bound in (15) when

$$\frac{\theta}{1 - \theta} \leq \nu. \tag{16}$$

Therefore, when (16) is satisfied, p_β must satisfy

$$\theta\nu < p_\beta \leq \frac{1}{2}(\theta\nu + \sqrt{(\theta\nu)^2 + 4\theta\nu}), \tag{17}$$

and for lower ν such that (16) is not satisfied, p_β must satisfy

$$\theta\nu < p_\beta \leq \nu. \tag{18}$$

It is straightforward to show that $\theta\nu < (1/2)(\theta\nu + \sqrt{(\theta\nu)^2 + 4\theta\nu})$ and to see that $\theta\nu < \nu$. Therefore, a range of p_β which satisfies (17) and (18) always exist.

At the same time that these conditions hold, firm α must not prefer to deviate from $p_\alpha = 1$ to a sufficiently low price that it captures the entire market. It could capture the entire market by setting p_α "just below" $1 - \nu + p_\beta$, which would result in profits just below $\pi_\alpha = 1 - \nu + p_\beta$. In any pure strategy equilibrium, this must be less than the expected π_α when firm α chooses $p_\alpha = 1$:

$\pi_\alpha = 1 - \theta\nu/p_\beta$. The firm has no incentive to deviate to a full market capture price if

$$1 - \nu + p_\beta \leq 1 - \frac{\theta\nu}{p_\beta}.$$

This inequality is only feasible when

$$\nu > 4\theta. \tag{19}$$

Otherwise, no values of $p_\beta \in (\theta\nu, \nu]$ exist satisfying the expression. Only when (19) is satisfied does there exist a value of p_β sufficiently close to $\nu/2$ such that firm α's best response does not involve setting a low enough p_α to capture the entire market. Firm α has no incentive to deviate to a value of p_α which captures the entire market as long as:

$$\frac{1}{2}(\nu - \sqrt{\nu^2 - 4\theta\nu}) \leq p_\beta \leq \frac{1}{2}(\nu + \sqrt{\nu^2 - 4\theta\nu}). \tag{20}$$

The upper bound on range (20) is always less than ν. We can show that $\theta\nu$ is at least as great as the lower bound on range (20) when

$$\frac{1}{1-\theta} \leq \nu \tag{21}$$

This means that when (21) is satisfied, a pure strategy equilibrium requires p_β such that

$$\theta\nu \leq p_\beta \leq \frac{1}{2}(\nu + \sqrt{\nu^2 - 4\theta\nu}). \tag{22}$$

When (21) is not satisfied, the necessary range of p_β is given by (20).

One can combine the above conditions on the parameters to determine the ranges of ν and θ such the a pure strategy equilibrium exists.

First, if (16) is not satisfied, i.e. if $\nu \leq \theta/(1-\theta)$, then (21) is also not satisfied, and a pure strategy equilibrium requires p_β satisfy both (18) and (20). In this case, (18) is redundant. Leaving only (20) as a restriction on p_β.

This entire case is only feasible when (19) is also satisfied, i.e. when $\nu \geq 4\theta$. This implies a more limited range of ν such that $4\theta \leq \nu \leq \theta/(1-\theta)$. It is straightforward to show that $4\theta \leq \theta/(1-\theta)$ if and only if $\theta \geq 3/4$. Furthermore, $\nu > 1$; a requirement that is redundant since $\theta \geq 3/4$ and $\nu > 4\theta$.

Second, if (16) is satisfied but (21) is not satisfied, i.e. if $\theta/(1-\theta) < \nu \leq 1/(1-\theta)$, then a pure strategy equilibrium requires p_β which satisfied both (17) and (20). This presents multiple possibilities, depending on which upper bound is more restrictive.

$$\frac{1}{2}(\theta\nu + \sqrt{(\theta\nu)^2 + 4\theta\nu}) < \frac{1}{2}(\nu + \sqrt{\nu^2 - 4\theta\nu})$$

whenever

$$\nu > \frac{4\theta}{1-\theta^2}. \tag{23}$$

Consider first case where (23) is satisfied. This means $4\theta/(1-\theta^2) < \nu \leq 1/(1-\theta)$. Such a range is feasible only when $4\theta/(1-\theta^2) < \nu \leq 1/(1-\theta)$, which is feasible only when $\theta < 1/3$. Furthermore, $4\theta/(1-\theta^2) > 1$ when $\theta > \sqrt{5}-2$. For lower values of θ, the lower bound is 1 rather than $4\theta/(1-\theta^2)$ since $\nu > 1$ is assumed by the model. This means that

$$\begin{array}{ccc} 1 < \nu \leq 1/(1-\theta) & \text{when} & \theta < \sqrt{5}-2 \\ 4\theta/(1-\theta^2) < \nu \leq 1/(1-\theta) & \text{when} & \sqrt{5}-2 \leq \theta < 1/3. \end{array} \tag{24}$$

Whenever one of these conditions is satisfied, there exists a pure strategy equilibrium whenever p_β is such that

$$\frac{1}{2}(\nu - \sqrt{\nu^2 - 4\theta\nu}) < p_\beta \leq \frac{1}{2}(\theta\nu + \sqrt{(\theta\nu)^2 + 4\theta\nu}). \tag{25}$$

Notice that (23) makes (19) redundant, meaning that in this case, $4\theta \leq \nu$ is always satisfied.

Next, consider the case where (23) is not satisfied. This means either $\theta/(1-\theta) < \nu \leq 4\theta/(1-\theta^2)$ and $\theta < 1/3$, or $\theta/(1-\theta) < \nu \leq 1/(1-\theta)$ and $\theta \geq 1/3$. For $\theta \leq \sqrt{5}-2$ (approx. 0.236), the required range of ν never exceeds 1, and is therefore infeasible given $\nu > 1$. Condition (19) must also be satisfied. One can show that $4\theta \geq \theta/(1-\theta)$ when $\theta \leq 3/4$, and $4\theta < 1/(1-\theta)$ and $4\theta < 4\theta/(1-\theta^2)$ are always satisfied.

Because product β provides some consumers a higher value than product α, it also must be the case that $\nu > 1$. One can show that $\theta/(1-\theta) \geq 1$ iff $\theta > 1/2$, and $4\theta \geq 1$ iff $\theta > 1/4$. For lower values of θ, the lower bounds should be 1 rather than $\theta/(1-\theta)$ or 4θ. Similarly, $4\theta/(1-\theta^2) > 1$ when $\theta > \sqrt{5}-2$. For lower θ, the upper bound in the case where $\theta \leq 1/3$ is below the minimum possible ν.

Therefore, the relevant range of ν when (16) is satisfied but (21) and (23) are not satisfied is

$$\begin{array}{ccc} 1 < \nu \leq \frac{4\theta}{1-\theta^2} & \text{when} & \sqrt{5}-2 < \theta \leq \frac{1}{4} \\ 4\theta < \nu \leq \frac{4\theta}{1-\theta^2} & \text{when} & \frac{1}{4} < \theta \leq \frac{1}{3} \\ 4\theta < \nu \leq \frac{1}{1-\theta} & \text{when} & \frac{1}{3} < \theta \leq \frac{3}{4} \\ \frac{\theta}{1-\theta} < \nu \leq \frac{1}{1-\theta} & \text{when} & \theta > \frac{3}{4}. \end{array} \tag{26}$$

In any of these parameter cases, a pure strategy equilibrium requires p_β such that

$$\frac{1}{2}(\nu - \sqrt{\nu^2 - 4\theta\nu}) < p_\beta \leq \frac{1}{2}(\nu + \sqrt{\nu^2 - 4\theta\nu}). \tag{27}$$

Third, if (21) is satisfied, i.e. if $\nu > 1/(1-\theta)$, then both (16) and (19) are also satisfied. This means that p_β must satisfy both (17) and (22). Combined, this again requires (25).

In summary,

1. Whenever $3/4 \leq \theta$ and $4\theta \leq \nu \leq \theta/(1-\theta)$, there exists a continuum of pure strategy equilibria in which $p_\alpha = 1$ and p_β is any value satisfying (20).

2. Whenever any combination of conditions in (24), or whenever $\nu > 1/(1-\theta)$ for any value of θ, there exists a pure strategy equilibrium in which $p_\alpha = 1$ and p_β is any value satisfying (25).

3. Whenever any combination of conditions in (26), there exists a continuum of pure strategy equilibrium in which $p_\alpha = 1$ and p_β is any value satisfying (27).

In aggregate, these conditions imply that a pure strategy equilibrium exists if and only if $\nu > \max\{4\theta, 1\}$.

In each of these equilibria, demonstration informativeness is given by (2) evaluated at $p_\alpha = 1$. That is,

$$d^* \mid_{p_\alpha=1} = \frac{p_\beta - \nu\theta}{p_\beta(1-\theta)} = \frac{1}{1-\theta} - \frac{\theta}{1-\theta}\frac{\nu}{p_\beta},$$

and consumer surplus equals 0.

Commitment to a fully informative demonstration policy

If a fully informative demonstration policy is committed to ahead of price competition, then firm β's price should not result in firm α's best response being to undercut and take the entire market.

Expected quality of product β is $\theta\nu/(1-(1-\theta)d_c)$. Will buy product β when realize favorable demonstration if $\theta\nu/(1-(1-\theta)d_c) - p_\beta \geq 1 - p_\alpha$. If p_α is just under $1 - \theta\nu/(1-(1-\theta)d_c) + p_\beta$, then take whole market and get profit equal to the same. Otherwise, get share $(1-\theta)d_c$ of the market at price $p_\alpha = 1$. Prefer not to deviate from $p_\alpha = 1$ as long as $(1-\theta)d_c \geq 1 - \theta\nu/(1-(1-\theta)d_c) + p_\beta$. Firm β gets payoff $\pi_\beta = (1-(1-\theta)d_c)p_\beta$ assuming that get favorable share of the market. Will prefer to set the highest p_β such that given p_α, will not lose entire market. So best response $p_\beta = \theta\nu/(1-(1-\theta)d_c) - 1 + p_\alpha$. Can show that when $p_\alpha = 1$ and $p_\beta = \theta\nu/(1-(1-\theta)d_c)$ that α has an incentive to take the whole market. No pure strategy equilibrium.

With $d_c = 1$, share θ of consumers have value ν for product β. If α targets those with no value for β, it sets price $p_\alpha = 1$. However, it's best response may be to undercut and take whole market. Suppose that firm β mixes according to F. If α sets $p_\alpha = 1$, it gets $\pi_\alpha = 1 - \theta$. If it sets a lower price, it gets

$$\Pr[1 - p_\alpha > \nu - p_\beta]p_\alpha + \Pr[1 - p_\alpha \leq \nu - p_\beta](1-\theta)p_\alpha$$

$$[(1 - F[\nu - 1 + p_\alpha]) + F[\nu - 1 + p_\alpha](1-\theta)]p_\alpha$$

$$[1 - F[\nu - 1 + p_\alpha]\theta]p_\alpha$$

Suppose this gives the same payoff as $p_\alpha = 1$:

$$[1 - F[\nu - 1 + p_\alpha]\theta]p_\alpha = 1 - \theta$$

$$F[\nu - 1 + p_\alpha] = [1 - (1-\theta)\frac{1}{p_\alpha}]\frac{1}{\theta}$$

Note that $p_\beta = \nu - 1 + p_\alpha$, and thus $p_\alpha = 1 - \nu + p_\beta$.

$$F[p_\beta] = [1 - (1-\theta)\frac{1}{1 - \nu + p_\beta}]\frac{1}{\theta}$$

$$F[p_\beta] = \frac{p_\beta + \theta - \nu}{(1 - \nu + p_\beta)\theta}$$

Minimum p_β is $p_\beta = \nu - \theta$. Maximum p_β solves $p_\beta + \theta - \nu = \theta - \theta\nu + p_\beta\theta$. That is $p_\beta(1-\theta) = \nu(1-\theta)$, or equivalently $p_\beta = \nu$.

Now, consider π_β. Setting $p_\beta = \nu$ results in $\pi_\beta = \nu\theta \Pr[p_\alpha = 1]$. Setting $p_\beta = \nu - \theta$ results in $\pi_\beta = \theta(\nu - \theta)$. Thus, $\Pr[p_\alpha = 1] = (\nu - \theta)/\nu$. Elsewhere,

$$\pi_\beta = \Pr[1 - p_\alpha \leq \nu - p_\beta]\theta p_\beta.$$

$$\pi_\beta = (1 - G[1 - \nu + p_\beta])\theta p_\beta.$$

$$(1 - G[1 - \nu + p_\beta])\theta p_\beta = \theta(\nu - \theta)$$

$$G[1 - \nu + p_\beta] = 1 - \frac{\nu - \theta}{p_\beta}$$

$$G[p_\alpha] = 1 - \frac{\nu - \theta}{p_\alpha - 1 + \nu}$$

This means lower bound on p_α solves $p_\alpha = 1 - \theta$. Except for $p_\alpha = 1$, which has mass $(\nu - \theta)/\nu$, the upper bound on p_α solves

$$1 - \frac{\nu - \theta}{p_\alpha - 1 + \nu} = 1 - \frac{\nu - \theta}{\nu}$$

$$\frac{\nu - \theta}{p_\alpha - 1 + \nu} = \frac{\nu - \theta}{\nu}$$

$$\nu = p_\alpha - 1 + \nu$$

$$p_\alpha = 1$$

Firm β earns $\theta\nu - \theta^2$ which is strictly less than its expected payoff in the game with endogenous d chosen after price competition. Expected consumer surplus, however, is strictly positive, and therefore committing the firms to provide fully informative demonstrations makes consumers better off (and maximizes total surplus).

Consumer surplus equals

$$(1-\theta)(1-p_\alpha)+\theta[\Pr[1-p_\alpha>\nu-p_\beta](1-p_\alpha)+\Pr[1-p_\alpha\leq\nu-p_\beta](\nu-p_\beta)]$$

This achieves its maximum value when p_β and p_α both draw their minimum values from the mixing distributions. That is, when $p_\beta=\nu-\theta$ and $p_\alpha=1-\theta$; in which case

$$(1-\theta)\theta+\theta[\Pr[1-p_\alpha>\nu-p_\beta]\theta+\Pr[1-p_\alpha\leq\nu-p_\beta]\theta]=\theta.$$

Therefore, the maximum possible consumer surplus when $d_c=1$ equals θ.

Now, suppose there are no demonstrations. This means that the expected value of good β is $\theta\nu$, compared to the value of good α which equals 1. If $\theta\nu\geq 1$, then the pricing equilibrium involves $p_\alpha=0$ and $p_\beta=\theta\nu-1$. In this case, $\pi_\alpha=0$, $\pi_\beta=\theta\nu-1$ and consumer surplus equals 1. If $\theta\nu<1$, then the pricing equilibrium involves $p_\alpha=1-\theta\nu$ and $p_\beta=0$. In this case, $\pi_\alpha=1-\theta\nu$, $\pi_\beta=0$ and consumer surplus equals $\theta\nu$.

Consumer surplus is maximized in the situation of no demonstrations compared to strategic demonstrations or full demonstrations. Although full demonstrations is not best for consumers, it is better than flexible demonstrations designed following price competition, which results in zero consumer surplus.

Firm β earns $\pi_\beta=\theta\nu$ under flexible demos, $\pi_\beta=\theta(\nu-\theta)$ under fully informative demos, and $\pi_\beta\in\{0,\nu-1\}$ under no demos. Full demos is never better than flexible demos, but is better than no demos when $\theta\nu<1$ or when both $\theta\nu\geq 1$ and $1+\theta>\nu$. No demos is better for firm β than full demos when both $\theta\nu\geq 1$ and $\nu>1+\theta$, and no demos is better than flexible demos when both $\theta\nu\geq 1$ and $\nu>1/(1-\theta)$.

A.3 ENDOGENOUS INNOVATION STRATEGIES: APPEAL

The main analysis takes the innovation's market appeal, represented by parameter θ, as fixed. In a variety of situations, however, firms make decisions influencing the appeal or marketability of their products.

In this section, we augment the game by allowing firm β to choose its product's appeal, θ, in the first stage of the game. The analysis focuses on the case in which improving product appeal is *costless*. We believe this is the most-realistic assumption in certain circumstances, but we also maintain this assumption to highlight the *strategic* determinants of product appeal. If the innovating firm prefers $\theta<1$ when improving appeal (or even releasing a product that appeals to everyone) is costless, then it must be doing so in order to influence the behavior of the other firm, not to reduce its product costs.

Our first result considers the endogenous choice of θ in the absence of demonstrations. The description of equilibrium outcomes in the absence of product demonstrations is provided in Section 5. When $\theta\nu<1$, firm β earns $\pi_\beta=0$, and when $\theta\nu\geq 1$, it earns $\pi_\beta=\nu\theta-1$, which is strictly increasing in θ. Therefore, absent demonstrations, π_β is maximized when $\theta=1$.

The first result establishes that the presence of informative demonstrations is necessary for an innovating firm to prefer release of a product with limited market appeal, even when releasing a more widely appealing product is costless. In the absence of informative demonstrations, products are always broadly appealing.

To see how products with limited appeal endogenously arise in our analysis, note that following any choice of θ, subgame perfect play is described by the game analyzed in Section 4. Consider first the choice of θ at the beginning of the subgame with flexible demonstrations. From the analysis of the (sub)game, we already know that each choice of θ can lead to one of two outcomes: a responsive equilibrium with flexibility when θ is relatively large (i.e. when $\nu < 4\theta/(1-\theta^2)$), or a non responsive equilibrium with flexibility, depending when θ is relatively small (i.e. when $\nu \geq 4\theta/(1-\theta^2)$). Rewriting these conditions in terms of θ gives

$$\nu \geq \frac{4\theta}{1-\theta^2} \iff 0 \leq \theta \leq \frac{1}{\nu}\left(\sqrt{\nu^2+4}-2\right), \tag{28}$$

$$\nu < \frac{4\theta}{1-\theta^2} \iff \frac{1}{\nu}\left(\sqrt{\nu^2+4}-2\right) < \theta \leq 1. \tag{29}$$

If choosing θ consistent with (28), firm β induces a non-responsive equilibrium, earning profit $\pi_\beta = \theta\nu$. Clearly, this is maximized by the maximum value of θ such that (28) holds, at which point $\pi_\beta = \sqrt{\nu^2+4}-2$. If choosing θ consistent with (29), firm β anticipates a responsive equilibrium, earning profit $\pi_\beta = (1+\theta)\nu/2 - 2\theta/(1+\theta)$. This profit function is convex in θ, and therefore achieves its maximum value at a corner, at either $\theta \to \frac{1}{\nu}\left(\sqrt{\nu^2+4}-2\right)$ or $\theta = 1$. As θ approaches the lower bound, its profits π_β approach $\theta\nu = \sqrt{\nu^2+4}-2$. Thus the profit function is continuous for all $\theta \in [0,1]$. At $\theta = 1$, profits are $\pi_\beta = \nu - 1$. The firm chooses between these values to maximize profits. Comparing the profit functions gives the following result.

- If $1 < \nu < 3/2$, then $\theta = (1/\nu)(\sqrt{\nu^2+4}-2)$. In this case, $\pi_\beta = \sqrt{\nu^2+4}-2$.
- If $3/2 \leq \nu$, then $\theta = 1$. In this case, $\pi_\beta = \nu - 1$.

Next, we consider the firm's optimal choice of θ when committed to a fully informative demonstration strategy. We have already shown that for any θ, firm β prefers to commit to a fully informative demonstration compared to any other level of informativeness. Thus, in the commitment subgame, $\pi_\beta = \theta(\nu - \theta)$. This expression is maximized at $\theta = \nu/2$, a value that is feasible given $\theta \in [0,1]$ only when $1 < \nu \leq 2$. Therefore,

- If $1 < \nu \leq 2$, then $\theta = \nu/2$. In this case, $\pi_\beta = \nu^2/4$.
- If $2 \leq \nu$, then $\theta = 1$. In this case, $\pi_\beta = \nu - 1$.

Comparing firm β's payoffs in the commitment and flexibility subgames, it is straightforward to show that when $\nu < 2$ the firm always prefers up front commitment over flexibility, and when $\nu > 2$ the firm is indifferent.

A.4 ENDOGENOUS INNOVATION STRATEGIES: VALUE ADDED

Throughout this the analysis, we assume that (i) $\theta > \sqrt{5} - 2$ and (ii) $k < \theta$. Inequality (i) reduces the number of equilibrium cases we need to consider in the body of the paper; the results can be generalized for lower θ. Inequality (ii) guarantees that firm β prefers to release an innovative product with $\nu > 1$ when it chooses to invest.

We begin by determining the firm's optimal choice of ν in the flexible demo subgame. First, consider the firm's preferred choice of ν conditional on the choice leading to a non responsive equilibrium outcome. From the analysis of the flexible demo subgame, we know that this requires $\nu \geq 4\theta/(1-\theta^2)$.

In this case, $\pi_\beta = \theta\nu - k\nu^2/2$. This is maximized at $\nu = \theta/k$. This value of ν satisfies the constraint on ν when $k > (1-\theta^2)/4$. For lower values of k, the optimal ν which leads to a non responsive equilibrium involves a corner solution with $\nu = 4\theta/(1-\theta^2)$.

- If $k \geq (1-\theta^2)/2$, then the optimal ν that leads to the non responsive equilibrium is $\nu = \theta/k$. In this case, $\pi_\beta = \theta^2/(2k)$.
- If $k < (1-\theta^2)/2$, then the optimal ν that leads to the non responsive equilibrium is $\nu = (1-\theta^2)/4$. In this case,

$$\pi_\beta = 4\theta^2(1-\theta^2-2k)/(1-\theta^2)^2. \tag{30}$$

Second, consider the firm's preferred choice of ν, conditional on the choice leading to the responsive equilibrium. From the analysis of the flexible demo subgame, we know that this requires $\nu < 4\theta/(1-\theta^2)$.

In this case, $\pi_\beta = (1+\theta)\nu/2 - 2\theta/(1+\theta) - k\nu^2/2$, which is maximized at $\nu = (1+\theta)/(2k)$. This value satisfies the constraint on ν when $k > (1+\theta)(1-\theta^2)/(8\theta)$. Otherwise, the optimal choice of ν involves $\nu \to 4\theta/(1-\theta^2)$.

- If $k \geq (1+\theta)(1-\theta^2)/(8\theta)$, then the optimal ν that leads to the responsive equilibrium is $\nu = (1+\theta)/(2k)$. In this case, plugging ν into the profit function gives $\pi_\beta = (1+\theta)^2/(8k) - 2\theta/(1+\theta)$.
- If $k < (1+\theta)(1-\theta^2)/(8\theta)$, then the optimal ν that leads to the responsive equilibrium is $\nu \to 4\theta/(1-\theta^2)$. In this case, π_β approaches the value in (30).

Together these results imply the three relevant ranges of k in Lemma 8.5. Above we have derived the equilibrium choice of ν and realized π_β for each of these ranges.

Having determined the equilibrium choices of ν, it is straightforward to calculate CS by plugging in the optimal values of ν to the relevant expressions for CS. We summarize the equilibrium outcome referring to the following threshold values of k:

$$\bar{k}_1 \equiv \frac{1-\theta^2}{4} \quad \text{and} \quad \bar{k}_2 \equiv \frac{(1+\theta)(1-\theta^2)}{8\theta}.$$

In equilibrium of the subgame with endogenous ν and flexible demonstrations, firm β chooses

$$\nu = \begin{cases} \theta/k & \text{when} \quad k < \bar{k}_1 \\ 4\theta/(1-\theta^2) & \text{when} \quad k \in [\bar{k}_1, \bar{k}_2) \\ (1+\theta)/(2k) & \text{when} \quad k \geq \bar{k}_2 \end{cases}$$

with payoffs

$$\pi_\beta = \begin{cases} \theta^2/(2k) & \text{when} \quad k < \bar{k}_1 \\ 4\theta^2(1-\theta^2-2k)/(1-\theta^2)^2 & \text{when} \quad k \in [\bar{k}_1, \bar{k}_2) \\ (1+\theta)^2/(8k) - 2\theta/(1+\theta) & \text{when} \quad k \geq \bar{k}_2 \end{cases}$$

$$CS = \begin{cases} 1-(1-\theta^2)/(4k) & \text{when} \quad k < \bar{k}_1 \\ 0 & \text{when} \quad k \geq \bar{k}_1 \end{cases}$$

Next, consider the firm's optimal choice of ν when it must commit to a demonstration policy in the first stage of the game. We have already established that for every ν, the firm prefers fully informative demos to any other level of commitment. Therefore, following the choice of ν, the firm commits to a fully informative demonstration strategy, $d = 1$. Given this, the firm expects profits $\pi_\beta = \theta(\nu - \theta) - k\nu^2/2$, which is maximized by setting $\nu = \theta/k$, which results in realized profits $\pi_\beta = \theta^2/(2k) - \theta^2$. This expression is only positive when $k < 1/2$. Therefore,

- If $k \leq 1/2$, then with commitment to a demo, firm β sets $\nu = \theta/k$ and earns profits $\pi_\beta = \theta^2/(2k) - \theta^2$.
- If $k > 1/2$, then with commitment to a demo, firm β sets $\nu = 0$ and earns $\pi_\beta = 0$.

It is straightforward to calculate CS given these values of ν. If $k \leq 1/2$ then $CS = \theta^2$, and if $k > 1/2$ then $CS = 0$.

Comparing payoffs between the flexible demo and commitment subgames shows that in equilibrium of the game with endogenous ν, CS and total surplus are both (weakly) higher under full commitment than under flexible demonstrations. π_β is strictly lower under full commitment for sufficiently low or sufficiently high k.

In the game with endogenous ν, consumers are never hurt and may be made better off by commitment to a fully informative demonstration. This is in contrast to the game in which ν is fixed, where commitment to a fully informative demonstration sometimes hurt consumers. Here, firm β tends to be hurt by commitment to a fully informative demonstration. The exception is for a parameter case in which k is close to $1/2$, in which case full commitment may simultaneously benefit the firm and the consumer.

Finally, one can compare payoffs to show that in equilibrium of the game with endogenous ν, CS, total surplus and π_β are all strictly higher under commitment to fully informative demonstrations when

$$\frac{(1+\theta)(1+3\theta)}{8\theta(2+\theta)} < k < \frac{1}{2}.$$

The condition on k is only feasible when θ is sufficiently large. Only when it is satisfied will firm β prefer commitment to a fully informative demonstration, and unlike in the earlier sections, here consumers may be made better off when the firm willingly commits. Thus, when the value added of the product (to the share of the market for which it is appealing) is endogenous, the conflict of interest between the innovating firm and consumers may be softened. Firm β may willingly commit to a fully informative demonstration design and this commitment may improve consumer surplus.

A.5 GENERAL INFORMATION STRUCTURE

In this section of the Appendix, we show how the binary class of signals assumed in our analysis arises endogenously in a more abstract theoretical setting in which we place minimal constraints on the firms ability to design a demonstration policy. Here, we model the demonstration as a signal from which consumers draw realizations prior to making a purchase decision; specifically, the demonstration is represented by a random variable Σ, jointly distributed with the consumer's valuation. Observing prior beliefs θ, the demonstration (signal) Σ, and the demonstration realization σ, each customer updates her posterior belief about her true value v_β according to Bayes' rule. Following the approach of Kamenica and Gentzkow (2011), we place minimal restrictions on the class of signals the firm may choose from. Although we allow for considerable generality in the strategic design of the demonstration Σ, the equilibrium demonstration always takes an intuitive form. We show that the equilibrium product demonstration requires two realizations, one "good" and one "bad." A consumer with a high value only observes a good realization, while a consumer with a low value may observe either realization. Thus, the equilibrium demonstration either reveals to the consumer that her value for the product is low, or increases her belief that her value is high (though it does not necessarily convince her that her value is high for certain).

In this section, we derive the sequentially rational demonstration provided by firm β, employing the approach of signal design or "Bayesian Persuasion," developed by Kamenica and Gentzkow (2011). These authors develop methods to study a general class of persuasion games but do not focus, as we do, on the interaction of optimal signal design and pricing in a product market.

Because prices have already been set, the firm designs a demonstration to maximize the portion of consumers that purchase its product. A demonstration is represented by a random variable, Σ, jointly distributed with the consumer's valuation. We represent this random variable as a pair of conditional random variables (Σ_H, Σ_L). To streamline exposition, we focus on random variables (Σ_H, Σ_L) that can take on an arbitrary but finite number of realizations.[21] An individual customer with true value $v_\beta = v_H$ observes an independent realization from Σ_H and a customer with true value $v_\beta = v_L$ observes an independent realization from Σ_L prior to purchase. The realization, which we refer to as the consumer's *impression* of the product, conveys information about the consumer's valuation. For example, if a customer observes a demonstration realization which is in the support

[21] With a more elaborate construction, we could easily incroporate continuous random variables into the analysis. Proposition A.2 will continue to hold in the more general setting. Hence, allowing the continuous random variable adds no additional insight into the analysis.

of Σ_H but not in the support of Σ_L, then the customer can correctly infer that she has a high value for the product. Similarly, if a customer observes a demonstration outcome in the support of Σ_L but not in the support of Σ_H, then she infers that her value is low. If a customer observes a demonstration outcome in the support of both Σ_H and Σ_L, then some valuation uncertainty remains, and the consumer updates her beliefs according to Bayes' rule. The customer's updated beliefs thus depend on the prior and the relative likelihood that the signal realization was generated by Σ_H and Σ_L.

Following the signal design approach, we first describe a representation of demonstration policies that considerably simplifies the analysis of this stage of the game. A customer's purchase decision is determined by her posterior belief about v_β. At the time firm β designs the demonstration, the only payoff-relevant aspect of the demonstration is the probability distribution it generates over the customer's posterior belief. We therefore represent any feasible demonstration $\Sigma = (\Sigma_H, \Sigma_L)$ by an alternative random variable Θ from which the customer's posterior belief about v_β is drawn. Suppose that demonstration (Σ_H, Σ_L) produces a realization σ. Observing σ, the prior θ, and the design of the demonstration (Σ_H, Σ_L), the customer updates her beliefs about the probability that $v_\beta = \nu$. Thus, each realization of the demonstration generates a posterior belief, $\hat{\theta} = Pr(v_\beta = \nu | \Sigma = \sigma)$, and the demonstration design also induces a probability distribution over these realizations. Once the demonstration has been designed, but before it is realized, the consumer's posterior belief is thus a random variable. The *ex ante* posterior belief is therefore given by random variable $\Theta = Pr(v_\beta = \nu|\Sigma)$, and this random variable captures all payoff-relevant aspects of the underlying demonstration. The Law of Total Expectation (and Bayesian rationality) implies that the expected value of the posterior belief is equal to the prior, θ. In the following Lemma (which forms the basis of the Bayesian Persuasion approach), we show that this is the only substantive restriction on the *ex ante* posterior beliefs that can be generated by a valid demonstration.[22]

Lemma A.1 *Consider a random variable Θ with finite support confined to the unit interval and expectation θ. If the prior belief that $v_\beta = \nu$ is equal to θ, then there exists a demonstration (Σ_H, Σ_L) for which the ex ante posterior belief is Θ.*

Proof. Let Θ represent a random variable with finite support inside the unit interval. Thus $S \equiv \text{Support}[\Theta] = \{t_i\}_{i=1}^N$. Let $r_i = Pr(\Theta = t_i)$. By assumption, $E[\Theta] = \theta \Rightarrow \sum_{i=1}^N r_i t_i = \theta$. Consider signal Σ, defined by two conditional random variables (Σ_H, Σ_L). (Σ_H, Σ_L) are defined over S as follows:

$$Pr(\Sigma_H = t_i) = \frac{t_i r_i}{\theta} \quad \text{and} \quad Pr(\Sigma_L = t_i) = \frac{r_i(1-t_i)}{1-\theta}$$

Observe that the random variables defined above are indeed admissible random variables, because all probabilities are positive and sum to one (an immediate consequence of $\sum_{i=1}^N r_i t_i = \theta$).

By assumption, the prior belief that $v_\beta = \nu$ is given by θ. A realization of Σ is observed. By definition, if $v_\beta = \nu$ a realization of Σ_H is observed, and if $v_\beta = 0$ a realization of Σ_L is observed.

[22]Of course each realization represents a probability, random variable Θ therefore must have support confined to the unit interval. Because (Σ_H, Σ_L) have a finite number of realizations, so must Θ.

The support of Σ is identical to the support of Θ. The posterior belief conditional on the observed realization t_i is given by Bayes' Rule, as follows:

$$Pr(v_\beta = \nu|\Sigma = t_i) = \frac{\theta Pr(\Sigma_H = t_i)}{\theta Pr(\Sigma_H = t_i) + (1-\theta)Pr(\Sigma_L = t_i)} = \frac{t_i r_i}{t_i r_i + r_i(1-t_i)} = t_i$$

Thus the posterior belief that $v_\beta = \nu$ conditional on signal realization t_i is equal to the realization of the signal. Next, consider the probability that realization t_i is generated, i.e. $Pr(\Sigma = t_i)$.

$$Pr(\Sigma = t_i) = \theta Pr(\Sigma_H = t_i) + (1-\theta)Pr(\Sigma_L = t_i) = t_i r_i + r_i(1-t_i) = r_i$$

Hence, given the signal Σ defined by the conditional random variables (Σ_H, Σ_L), the posterior belief has the following properties:

$$Pr(v_\beta = \nu|\Sigma = t_i) = t_i \text{ and } Pr(\Sigma = t_i) = r_i$$

Which means that the probability that the posterior belief will be equal to t_i is equal to r_i. Hence the *ex ante* posterior belief random variable for this signal is Θ. ∎

This Lemma considerably simplifies the analysis. All payoff-relevant aspects of a possible demonstration are summarized by a single random variable representing the *ex ante* distribution of customers' posterior beliefs. The Lemma shows that any random variable with finite support inside $[0,1]$ and mean equal to the prior is the *ex ante* posterior belief for some demonstration design.[23] The analysis can therefore focus on an alternative version of our original game in which firm β chooses Θ rather than (Σ_H, Σ_L), as long as Θ has finite support in the unit interval and expectation θ. Through the remainder of this section, we refer to the choice of Θ as a choice of a demonstration, although Θ technically represents an entire payoff-equivalent class of demonstration designs.

Let $\hat{\theta}$ denote a consumer's the realization of Θ. That is, $\hat{\theta}$ is the posterior probability the consumer places on herself having high value for product β. Define $\hat{\mu} = \nu\hat{\theta}$, the consumer's posterior expected value of product β.

In the final stage of the game, a consumer purchases product β if her demonstration produces a realization $\hat{\mu}$ satisfying $\hat{\mu} \geq \bar{\mu}(p_\alpha, p_\beta)$, as defined in the body of the paper. This condition is equivalent to $\hat{\theta} \geq \bar{\mu}(p_\alpha, p_\beta)/\nu$ Therefore, firm β designs a demonstration Θ to maximize the probability that the consumer purchases its product:

$$\max_{\Theta} \quad Pr(\Theta \geq \bar{\mu}(p_\alpha, p_\beta)/\nu) \tag{31}$$

$$\text{s.t.} \quad E[\Theta] = \theta \quad \text{and} \quad Pr(0 \leq \Theta \leq 1) = 1$$

The equilibrium demonstration takes one of three forms, depending on the relative size of $\bar{\mu}(p_\alpha, p_\beta)$. First, a trivial case occurs when the consumer's purchase threshold exceeds one, $\bar{\mu}(p_\alpha, p_\beta) > \nu$.

[23] In fact, a large class of payoff equivalent demonstration policies.

Here, firm α has a sufficiently strong price advantage that even consumers who are certain that $v_\beta = \nu$ choose to purchase product α. In this case, no feasible demonstration generates demand for product β. In this situation, firm α has *captured* the entire market. Second, suppose that the threshold belief is below the prior: $\bar{\mu}(p_\alpha, p_\beta) < \theta\nu$; that is, the prior is sufficiently in favor of a high valuation for the innovation that $\hat{\theta} \geq \bar{\mu}(p_\alpha, p_\beta)/\nu$ is satisfied without any demonstration. Here, consumers are *predisposed in favor* of product β, and will purchase it based on the prior alone. By providing consumers with an informative pre-purchase demonstration, firm β introduces the possibility that a consumer receives a negative impression and chooses not to purchase its product. By providing no demonstration (or a demonstration that is never informative enough to overturn a consumer's priors), firm β guarantees that it sells its product to everyone. Here firm β's price is sufficiently low (or its expected valuation is sufficiently high) that β has captured the entire market. Third, if the consumer's threshold is between the prior and one, $\theta\nu < \bar{\mu}(p_\alpha, p_\beta) \leq \nu$, consumers are not be willing to purchase the innovation on the basis of the prior alone, but could be persuaded to purchase it by a good realization from an informative signal. The market is therefore *contested*.

Two intuitive observations simplify the solution of the signal design problem in a contested market. First, it is never optimal for firm β to "over-convince" a consumer to buy the innovation. A demonstration need only provide enough information to convince consumers that they prefer to purchase the product given prices. A demonstration that provides a customer with information than necessary may allow the customer to become more certain that she has a high value, but at the same time increases the chance that she learns something about the product that causes her to update her value negatively. Because a customer will buy a product regardless of whether she has a slight preference or a strong preference in favor of doing so, the firm aims for its demonstration to only marginally-convince, not over-convince, consumers, which reduces the probability of the consumer learning something detrimental.[24] If the consumer is willing to purchase the innovation when her belief $\hat{\mu}$ is $\bar{\mu}(p_\alpha, p_\beta)$, then the firm does not need to provide a demonstration that provides more information than is needed to generate such a belief. Second, a consumer does not purchase product β regardless of whether she observes a signal realization that leaves her moderately against purchase, or observes a signal realization that leaves her fully convinced that she has low valuation for the good. Rather than design a signal that potentially leaves a consumer moderately against purchase, firm β prefers to design a signal that ensures that all consumers who will not be willing to purchase the product know for certain that their value is zero. Doing so gives the firm the highest possible chance to generate a posterior belief that is sufficiently favorable that the consumer would purchase the innovation.[25] The equilibrium demonstration Θ therefore concentrates mass on only

[24] Technically, a consumer is willing to purchase the innovation for any posterior belief $\hat{\mu}$ greater than or equal to $\bar{\mu}(p_\alpha, p_\beta)$; by reallocating any probability on realizations above the switching threshold $\bar{\mu}(p_\alpha, p_\beta)$ onto the threshold, the firm does not change the probability of making a sale. However, by doing so, it reduces the expected value of Θ, which allows it to then reallocate probability from realizations below $\bar{\mu}/\nu$ (which do not lead to sales) onto $\bar{\mu}/\nu$ while preserving the mean constraint. Because realizations of Θ below $\bar{\mu}/\nu$ do not generate sales, but realization $\bar{\mu}/nu$ does, this reallocation increases the probability of making a sale without violating the constraints.

[25] Technically, the firm can reallocate all probability on realizations that do not lead the consumer to purchase the innovation onto realization zero, without reducing the probability of making a sale. By doing so, the firm reduces the expected value of Θ, and can therefore re-allocate probability onto a realization at $\bar{\mu}/\nu$ in order to satisfy the

two posterior beliefs, $\hat{\theta} = 0$ and $\hat{\theta} = \bar{\mu}(p_\alpha, p_\beta)/\nu$. From here it is simple to calculate the equilibrium demonstration:

$$Pr(\Theta = \bar{\mu}(p_\alpha, p_\beta)/\nu) = \frac{\theta\nu}{\bar{\mu}(p_\alpha, p_\beta)} \quad \text{and} \quad Pr(\Theta = 0) = 1 - \frac{\theta\nu}{\bar{\mu}(p_\alpha, p_\beta)} \tag{32}$$

Because it generates only two posterior beliefs, the equilibrium demonstration can always be implemented using only two potential realizations, one "bad" and one "good." A bad signal realization reveals to the consumer that $v_\beta = 0$, while the good realization is just strong enough to convince the consumer to purchase product β. Firm α therefore sells to all consumers who experience a negative impression of product β in the demonstration, as these consumers learn that $v_\beta = 0$. Firm β sells to the consumers who do not experience a negative impression of their product. Although these consumers may not be completely certain that they have a high value for product β, the fact that they did not receive a negative impression leaves them just confident enough to purchase the new product instead of the established alternative.

Although we place no limit on the design of the demonstration chosen by firm β, its equilibrium choice may always be implemented by a signal with an intuitive structure.

Proposition A.2 *There exists a value $d \in [0, 1]$ such that the equilibrium demonstration Θ^* is generated by a binary signal $\Sigma^* = (\Sigma_H^*, \Sigma_L^*)$ with potential realizations $\sigma \in \{G, B\}$, where*

$$Pr(\Sigma_H^* = G) = 1, \quad Pr(\Sigma_H^* = B) = 0,$$

$$Pr(\Sigma_L^* = G) = 1 - d, \quad Pr(\Sigma_L^* = B) = d.$$

Proof. Consider the following maximization problem:

$$\max_{\Theta} \quad Pr(\Theta \geq \bar{\mu}(p_\alpha, p_\beta)/\nu)$$

$$\text{s.t.} \quad E[\Theta] = \theta \quad \text{and} \quad Pr(0 \leq \Theta \leq 1) = 1$$

Adopt the same notation as in the proof of Lemma A.1 above. If $\bar{\mu}/\nu > 1$ or $\bar{\mu}/\nu \leq \theta$, then either all signals are equivalent, or an uninformative signal is optimal. In these cases the result is obvious. Consider therefore the case in which $\theta < \bar{\mu}/\nu \leq 1$.

Suppose that there exists a realization of Θ, denoted t, such that $0 < t < \bar{\mu}/\nu$. Consider an alternative random variable Θ', identical to Θ, except that probability on t, denoted r, is redistributed to two other realizations $\{t(1-\epsilon), \bar{\mu}/\nu\}$. Let r_ϵ denote the reallocated probability assigned to realization $t(1-\epsilon)$, and $\tilde{r}$ denote reallocated probability added to $\bar{\mu}/\nu$.

$$\tilde{r} = r\frac{t\epsilon}{t\epsilon + \bar{\mu}/\nu - t} \quad \text{and} \quad r_\epsilon = r(1 - \frac{t\epsilon}{t\epsilon + \bar{\mu}/\nu - t})$$

constraint. Because realization $\bar{\mu}/\nu$ does lead the consumer to purchase, reallocating probability in this way increases the probability of making a sale without violating the constraints.

Notice that for ϵ the increase in probability on θ is arbitrarily small, and therefore for sufficiently small ϵ adding this probability to any already on $\bar{\mu}/\nu$ is feasible, i.e. small ϵ can always be found such that $Pr(\Theta' = \bar{\mu}/\nu) \in (0,1)$. A sufficiently small ϵ can be chosen for which $t(1-\epsilon)$ is not part of the support of Θ; for the transformed random variable $Pr(\Theta' = t(1-\epsilon)) \in (0,1)$. By construction,

$$r_\epsilon + \tilde{r} = r \quad \text{and} \quad r_\epsilon t(1-\epsilon) + \tilde{r}\bar{\mu}/\nu = tr$$

thus, this transformation is indeed a valid reallocation of probability, which also does not change the expected value of the random variable. Observe that

$$Pr(\Theta' \geq \bar{\mu}/\nu) = Pr(\Theta \geq \bar{\mu}/\nu) + \tilde{r}$$

Because $\bar{\mu}/\nu > t$, this increase $\tilde{r} > 0$. Hence the transformed random variable has a greater probability of being greater or equal to $\bar{\mu}/\nu$. Because it increases the probability of realization $\bar{\mu}/\nu$, such a reallocation increases the value of the objective function. Therefore, if Θ is the solution of this maximization problem, no realization (with positive probability) exists in interval $(0, \bar{\mu}/\nu)$.

Now suppose that there exists a realization of Θ, denoted t, such that $\bar{\mu}/\nu < t \leq 1$. Consider an alternative random variable Θ', identical to Θ, except that probability on t, denoted r, is redistributed to two other realizations $\{t(1-\epsilon), 0\}$. Let r_0 denote the reallocated probability assigned to realization 0, and r_ϵ denote reallocated probability assigned to $t(1-\epsilon)$.

$$r_\epsilon = r(1 + \frac{\epsilon}{1-\epsilon}) \quad \text{and} \quad r_0 = -r\frac{\epsilon}{1-\epsilon}$$

Because $E[\Theta] = \theta$, it must be that $Pr(\Theta \leq \theta) > 0$. Because $\theta < \bar{\mu}/\nu$ (by assumption) it must be that $Pr(\Theta < \bar{\mu}/\nu) > 0$. As established above, all probability mass in $[0, \bar{\mu}/\nu)$ is on realization 0, that is, $Pr(\Theta < \bar{\mu}/\nu) = Pr(\Theta = 0)$. Hence $Pr(\Theta = 0) > 0$. Thus a sufficiently small ϵ can be found that the adjustment described above does not make the probability on zero negative. The probability on $t(1-\epsilon)$ is marginally greater than r, and is thus also less than one.

$$r_0 + r_\epsilon = r \quad \text{and} \quad r_0(0) + r_\epsilon t(1-\epsilon) = tr$$

thus, this transformation is indeed a valid reallocation of probability, which also does not change the expected value of the random variable. Observe that

$$Pr(\Theta' \geq \bar{\mu}/\nu) = Pr(\Theta \geq \bar{\mu}/\nu) + \frac{\epsilon}{1-\epsilon}$$

Because it increases the probability of being above Θ, such a transformation increases the payoff function. Therefore, if Θ is the solution of this maximization problem, no realization (with positive probability) exists in interval $(\bar{\mu}/\nu, 1)$.

Combining these results implies that the optimal demonstration concentrates mass on only two realizations $\{0, \bar{\mu}/\nu\}$. To calculate the probability of each realization appeal to the mean constraint:

$$Pr(\Theta = \bar{\mu}/\nu)\bar{\mu}/\nu = \theta \Rightarrow Pr(\Theta = \bar{\mu}/\nu) = \frac{\theta}{\bar{\mu}(p_\alpha, p_\beta)/\nu}$$

Thus optimal random variable Θ is the following Bernoulli random variable:

$$Pr(\Theta = \bar{\mu}/\nu) = \frac{\theta}{\bar{\mu}(p_\alpha, p_\beta)/\nu} \quad \text{and} \quad Pr(\Theta = 0) = 1 - \frac{\theta}{\bar{\mu}(p_\alpha, p_\beta)/\nu}$$

Applying the transformation described in proof of Lemma A.1 to generate the signal (Σ_H, Σ_L) from the posterior belief random variable gives: efined over S as follows:

$$Pr(\Sigma_H = \bar{\mu}/\nu) = 1$$

$$Pr(\Sigma_L = \bar{\mu}/\nu) = \frac{\frac{\theta}{\bar{\mu}(p_\alpha, p_\beta)/\nu}(1 - \bar{\mu}(p_\alpha, p_\beta)/\nu)}{1-\theta} = \frac{\theta}{1-\theta}\frac{1 - \bar{\mu}(p_\alpha, p_\beta)/\nu}{\bar{\mu}(p_\alpha, p_\beta)/\nu}.$$

Relabeling the names of the realization of Σ_H, Σ_L to (G, B) and defining

$$\gamma \equiv \frac{\theta}{1-\theta}\frac{1 - \bar{\mu}(p_\alpha, p_\beta)/\nu}{\bar{\mu}(p_\alpha, p_\beta)/\nu}$$

gives the optimal demonstration characterized in the proposition. ■