The Optimal Choice of Pre-Launch Reviewer*

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Abstract

We develop a framework in which: (i) a firm can have a new product tested publicly before launch; and (ii) tests vary in *toughness*, holding *expertise* fixed. Price flexibility boosts the positive impact on consumer beliefs of passing a tough test and mitigates the negative impact of failing a soft test. As a result, profits are convex in toughness: the firm selects either the toughest or softest test available. The toughest test is optimal when consumers start with an unfavorable prior and receive sufficiently uninformative private signals (an "innovative" product); the softest test is optimal when signals are sufficiently informative.

Keywords: test, reviewer, certification, Bayesian learning, information transmission, marketing, product launch, bias, tough test, soft test.

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1 Introduction

Should a software company launching a new product invite a skeptical reviewer to preview the product or should it restrict previewing opportunities to soft reviewers known to be positively predisposed towards the company's products? How should the sponsor of a new technology choose between standard-setting organizations of varying toughness ranging from fully independent to largely captive? Should a politician seeking election restrict interview opportunities to media outlets with similar political leanings, or should the politician instead agree to face a challenging interview with a media outlet from the opposite side of the political spectrum?

In this paper we develop a framework to study such questions. In our framework, a monopolist can choose to have a new product tested publicly before launching the product on the market. The firm knows the quality of the new product (either high or low), but is unable to disclose quality verifiably to imperfectly informed consumers. Instead, the firm attempts to transmit information about quality by selecting among tests which vary in *toughness*, holding *expertise* fixed. In selecting the toughness of the test to be faced, the firm trades off the higher probability of passing a softer test against the greater impact on consumers' beliefs from passing a tougher test. The firm also chooses the new product's price, which can be conditioned both on the publicly known toughness of the chosen test and on the test's pass or fail decision. We want to discover both what sort of test a monopolist might choose and how the choice of test interacts with pricing: in short, we want to analyze the best way for the monopolist to use public tests together with prices to maximize profits.

In our framework, a monopolist with a low quality product can duplicate costlessly the actions of a high quality monopolist. Therefore, all our equilibria will be pooling, and hence the monopolist cannot use the choice of test or price to signal her product quality directly. Nevertheless, tests play a crucial role in information transmission, not through the *choice* of test but through the *outcome* of the test and the interaction of the test and pricing.

We find that the monopolist always chooses to have her new product publicly tested before launch: in fact any test is better than not being tested at all. We also find that the monopolist always selects either the toughest or softest public test available to her: the ability to condition price on the test decision convexifies profits by bolstering the strong positive impact of passing a tough test and mitigating the strong negative impact of failing a soft test. When consumers start with an unfavorable prior and receive sufficiently uninformative private signals, which might correspond to an innovative product about which consumers receive little private information, the monopolist chooses the toughest possible test to maximize the impact of passing the test. In that case, the monopolist accepts a high risk of failing the test in order to launch her new product with a bang if she passes. If, on the other hand, consumers' signals are very informative, perhaps because the type of product is well-known, the softest test is chosen to maximize the probability of passing.

Our results can help to shed light on why firms might sometimes choose very tough public tests or reviewers, while on other occasions they restrict reviewing opportunities to "yes-men". In Section 5, we link our model and results to two specific applications and discuss the applicability of our framework to broader situations in which a principal seeks endorsement from a group of agents and outside certification of quality is available.

Section 2 describes how our analysis relates to the existing literature. Section 3 outlines the structure of our model. Section 4 presents our results. Section 5 provides discussion and applications. Section 6 concludes. All proofs are relegated to the appendix.

2 Related literature

The literature has paid almost no attention to the use of public tests of varying toughness to transmit information. [17] examine the choice of certifier by owners of intellectual property (or sponsors of an idea) to persuade potential users of the idea's quality. Their focus is on the role of biased technology standard-setting authorities as certifiers, but they also examine the welfare implications of certifier market power.[1] [13] consider the problem facing a principal who knows her product quality, seeks to promote her product and can use a biased test to help convince agents (who act in strict sequence) to endorse her. Crucially, in these papers there is no role for prices conditioned on the test's decision: in [17] the certifier's decision rule is sensitive to any anticipated price response to its decision, while [13] study fixed-price contexts. We allow pricing flexibility and thereby examine the interplay between the choice of test and the optimal price, finding that the ability to condition price on the toughness of the chosen test and on whether the product

[1] [10] empirically test [17]'s model, while [12] extend the model to a dynamic setting.

passes or fails generates the convexity in the monopolist's profit function which drives the choice of test to an extreme. This completely overturns the main result in [13] that a very mildly tough test is best and in [17] that the principal prefers the certifier most biased in favor of the new technology, subject to users adopting following certification. In both cases, the inability to use price to bolster the impact of passing a tough test or mitigate the impact of failing a soft test makes very tough or very soft tests unattractive.

The framework studied in [17] is also different from ours since the principal is not perfectly informed about the quality of its technology, the chosen certifier discovers with certainty the quality of the technology it is asked to certify and users do not receive any private information. The framework in [13] can be seen as a highly simplified analog of the one we study here, but with fixed prices. Instead of allowing the distribution of private beliefs about quality to take any continuous shape as we do, [13] assume that their agents start with a common symmetric prior belief equal to the "price" of endorsement and receive a private signal from a quality-dependent Bernoulli distribution, resulting in a simple two-point distribution of private beliefs. The tester receives two signals from the same Bernoulli distribution from which the agents receive their private signals, and the toughness of the test is the probability of failing when the tester receives two conflicting signal outcomes. A very mildly tough test is preferred, since passing such a test is just enough to induce those agents who received the bad private signal outcome to endorse and thereby start a cascade on endorsement.

In our set-up testing has no direct cost to the monopolist; hence all equilibria are pooling. Thus we abstract from [29]-style signaling of quality through the choice of test. [14] studies the case in which a firm can use the choice of test to signal quality directly in the context of a model with certification fees and two types of test.

Early pricing and marketing strategy can sometimes play a role similar to tough and soft tests. For example, [31] and [3, 4] find that high initial prices, whose effects are similar to the choice of a tough test, can be optimal. By contrast, in [7, 8], in which early prices are unobservable to later consumers, and in [32], in which prices cannot be conditioned on the history of purchases, low introductory prices are preferred. [21] find that low initial marketing expenditure, which operates in a way analogous to a soft test by inducing fewer consumers to consider the product and acquire private signals, can be best.

Some papers consider the use of tests and experts in the absence of a public choice over test toughness. [23] find that, to reduce a buyer's informational rents, a seller may wish to use a public signal of quality which is affiliated with the buyer's private information. [9, ch. 10] surveys the literature on self-interested experts, while [30] considers the capture of certification intermediaries. [26] and [5] consider multiple public decisions made by consumers at the start of a product's life-cycle which act in a similar way to a public test. Our paper also falls into the broader literature on the efficiency of information transmission dating at least from the seminal contribution of [2]. The auction literature, for example, has considered the different information structures a seller should make available to potential buyers about their heterogeneous valuations ([1]) and how much information *buyers* should spend to acquire signals about product quality ([24]).

Finally, the convexity of profits in test toughness in our set-up is reminiscent of the findings in [18] and [15] that a monopolist's profit is convex in the amount of information released to consumers; therefore the monopolist will choose to release either as much or as little information as possible. However, the mechanism in those papers is different: the monopolist is choosing how much to rotate the demand curve since information release allows consumers to discover how well the product matches their idiosyncratic tastes. Our tests, on the other hand, shift demand in and out for consumers who all share the same preferences and hence are learning about objective quality.

3 Model

A monopolist launches a new product aimed at a unit mass of potential consumers with unit demands. The product's quality $v \in \{0, 1\}$ is either high ($v = 1$) or low ($v = 0$). Consumers are risk neutral and receive utility $v - p$ from buying at a price p and zero otherwise. The monopolist knows the quality of her product, but cannot verifiably disclose this information. Normalizing marginal costs to zero, the monopolist aims to maximize expected revenue.

Each consumer receives a private signal about product quality, defined to be an i.i.d. random draw from a continuous quality-dependent signal distribution. Each consumer uses her signal outcome (the realization of her random draw) together with her prior belief to form a private belief π about the probability that the product is of high quality. We assume that the quality-dependent cumulative distribution function over the consumers' private beliefs is known to the monopolist and is continuous with support $[\underline{\pi}, \overline{\pi}]$, where $0 < \underline{\pi} < \overline{\pi} < 1$ so that the beliefs are bounded and thus no private signal outcome perfectly reveals quality. We let $G(\pi)$ represent the distribution function over private beliefs when the product is of high quality. This formulation places no particular restriction on the prior beliefs: before they receive their private signals, the consumers can start with priors which are either common to all consumers or heterogeneous across consumers.[2]

The monopolist chooses whether or not to subject her new product to a pre-launch public test. If the monopolist chooses to be tested, the test returns a binary decision $d \in \mathbb{D} \equiv \{P, F\}$ where P is a pass and F is a fail.[3] The probability of decision d given quality v is given by $q_v^d \in [0,1]$, with $\sum_{\mathbb{D}} q_v^d = 1$, which implies that $q_1^P - q_0^P = q_0^F - q_1^F$. Conditional on quality, the test decision is independent of the consumers' private signals. To ensure that a pass is good news about product quality and that a fail is bad news, we assume that

$$\kappa \equiv q_1^P - q_0^P = q_0^F - q_1^F > 0. \tag{1}$$

In the language of [22], a pass is "more favorable" news than a fail since the Monotone Likelihood Ratio Property is satisfied. We think of κ as measuring the *expertise* of the test, which from the monopolist's perspective is fixed. However, the monopolist can choose the *toughness* of the test, measured by

$$\tau \equiv q_1^F = 1 - q_1^P, \tag{2}$$

and the consumers observe this choice of τ. Given κ, tougher tests are harder to pass, whatever the product quality: a tougher test implies a higher rate of false negatives (where the high quality product fails the test) and a lower rate of false positives (where the low quality product passes). The monopolist chooses $\tau \in [0, 1-\kappa] \cup N$; the *softest test* has $\tau = 0$, while the *toughest test* has $\tau = 1-\kappa$ given $q_0^F \leq 1$, and $\tau = N$ represents the choice not to be tested. We assume $\kappa < 1$; otherwise the toughest and softest tests coincide, and hence the monopolist does not face a choice of toughness.

[2]If the consumers start with a fair prior (i.e., before receiving her private signal each consumer believes that the product is of high quality with probability $\frac{1}{2}$), without loss of generality we can assume that the private signal outcomes and the private beliefs coincide (see [28]).

[3]Modeling a test (or an evaluator) as condensing more complex information into a simple binary decision is a common assumption in the literature. For example see [6], [25], [17], [11] and [16]. As [6, p. 534] puts it: "This feature represents the basic nature of advice, a distillation of complex reality into a simple recommendation."

The monopolist chooses a price p for her product which can be conditioned on product quality v, the toughness of the selected test τ and, if $\tau \neq N$, the test's decision d. After observing the choice of test τ, the test's decision d (if $\tau \neq N$) and the chosen price p, each consumer updates her private belief π to form a posterior belief π' about the probability that the product is of high quality. Since each consumer is risk neutral, this posterior belief equals the consumer's expected utility from purchasing net of the price, and hence the consumer buys if and only if $\pi' \geq p$. The consumers make their purchasing decisions simultaneously.

4 Results

4.1 Restriction to high quality monopolist's choice of pooling equilibrium

We solve for perfect Bayesian equilibria, and we restrict attention to pure strategies. In our framework, a monopolist with a low quality product can duplicate costlessly the actions of a high quality monopolist. As a result, apart from degenerate separating equilibria in which the monopolist always earns zero revenue, all equilibria must be pooling. Suppose not: in a separating equilibrium a monopolist with a low quality product would reveal her quality to be low the first time her choice of test τ or price p differed from that of a monopolist with a high quality product; at that point, the monopolist would instead prefer to deviate and duplicate the strategy of the high quality monopolist.[4] Thus the monopolist cannot use the choice of test or price to signal her product quality directly, and hence we focus attention on the direct role of the test itself in transmitting information to the consumers, who learn only from the test decision.

We restrict attention to the pooling equilibria in which, conditional on pooling, the monopolist with a high quality product chooses her preferred test τ and conditional pricing rule. Such equilibria can be supported by the off-equilibrium belief that a deviator's product is of low quality. These pooling equilibria are appealing since it is the low quality monopolist which would like to masquerade as the high quality monopolist, and not the reverse. Indeed, such pooling equilibria are the only strongly undefeated perfect Bayesian

[4] For simplicity, we do not consider mixed strategy equilibria; however, if we allowed mixed strategies, semi-separating equilibria in which one type of monopolist mixed and the other did not at a particular choice would be ruled out.

equilibria.[5]

4.2 Deriving the revenue function

We now derive the high quality monopolist's revenue function, conditional on pooling. If the monopolist chooses to be tested, using Bayes' Rule the posterior belief π' of a consumer with private belief $\pi \in [\underline{\pi}, \overline{\pi}]$ after observing a test decision d is given by:

$$\pi'_d = \frac{q_1^d \pi}{q_1^d \pi + q_0^d (1-\pi)}. \tag{3}$$

After a test pass ($d = P$), the posterior belief is given by:

$$\pi'_P = \frac{q_1^P \pi}{q_1^P \pi + q_0^P (1-\pi)} = \frac{(1-\tau)\pi}{(1-\tau)\pi + (1-\tau-\kappa)(1-\pi)} \in (\pi, 1]. \tag{4}$$

For the toughest test ($\tau = 1-\kappa$), a pass reveals the quality to be high for sure; hence $\pi'_P = 1$. Passing any other test leaves $\pi'_P \in (\pi, 1)$. After a test fail ($d = F$), the posterior belief is given by:

$$\pi'_F = \frac{q_1^F \pi}{q_1^F \pi + q_0^F (1-\pi)} = \frac{\tau\pi}{\tau\pi + (\tau+\kappa)(1-\pi)} \in [0, \pi). \tag{5}$$

For the softest test ($\tau = 0$), a fail reveals the quality to be low for sure; hence $\pi'_F = 0$. Failing any other test leaves $\pi'_F \in (0, \pi)$. If the monopolist chooses not to be tested, the consumers' private beliefs are unaltered; hence $\pi' = \pi$.

After a test decision d, the monopolist can sell to the proportion of consumers $1 - G(\pi)$ whose private beliefs are at least as good as π by setting price p equal to the posterior belief π'_d of a consumer whose private belief exactly equals π. Thus, conditional on the

[5] Strongly undefeated perfect Bayesian equilibrium (SUPBE), due to [20], is a variant of [19]'s undefeated perfect Bayesian equilibrium (UPBE). Applied to our setting, a PBE is also a SUPBE if: (i) whenever there is an alternative PBE which is strictly preferred by just one type of monopolist, a deviation consistent with that type's equilibrium play in the alternative weakly increases consumer beliefs that the deviator is of that type (beliefs increase strictly if the other type of monopolist strictly prefers the original PBE); and (ii) whenever there is an alternative PBE which is strictly preferred by both types of monopolist, a deviation consistent with a given type's equilibrium play in the alternative must weakly increase consumer beliefs that the deviator is of that type. (In both cases, beliefs go to one if the other type's play in the alternative PBE is not consistent with the deviation.) If in our setting other equilibria were strongly undefeated, a deviation consistent with one of the high quality monopolist's preferred pooling equilibria would always weakly increase consumer beliefs that the deviator's product was of high quality, which would give the high quality monopolist an incentive to deviate. The high quality monopolist's preferred pooling equilibria are strongly undefeated since the off-equilibrium belief that a deviator's product is of low quality is consistent with SUPBE.

test decision d, maximal revenue for a high quality monopolist is given by:[6]

$$\max_{\pi} \pi'_d(1 - G(\pi)) = \max_{\pi} \frac{q_1^d \pi}{q_1^d \pi + q_0^d (1 - \pi)}(1 - G(\pi)). \tag{6}$$

A high quality monopolist who chooses to be tested anticipates the impact of the chosen test toughness τ and test decision d on her pricing decision, and therefore selects test toughness $\tau \in [0, 1 - \kappa]$ to maximize expected revenue across both possible test decisions, given by:

$$R = \sum_{\mathbb{D}} q_1^d \max_{\pi} \frac{q_1^d \pi}{q_1^d \pi + q_0^d (1 - \pi)} (1 - G(\pi)) = \sum_{\mathbb{D}} \max_{\pi} \frac{\left(q_1^d\right)^2 \pi (1 - G(\pi))}{q_1^d \pi + q_0^d (1 - \pi)}. \tag{7}$$

If the high quality monopolist chooses not to be tested, $\pi' = \pi$; therefore she will sell to a proportion $1 - G(\pi)$ of consumers by setting price $p = \pi$. Thus her maximal revenue is given by:

$$R = \max_{\pi} \pi(1 - G(\pi)). \tag{8}$$

4.3 Choosing to be tested

Our first substantive result is that the monopolist will always choose to subject a new product to a pre-launch public test.

Proposition 1. *The monopolist always opts to have a new product tested publicly before launch.*

The result is intuitive. In expectation, a test reveals good information about a high quality product, and hence the monopolist who knows her product quality to be high is keen for consumers to have this information. A low quality monopolist is then forced to face a test to avoid revealing low quality by refusing to be tested. In fact, the proof of Proposition 1 shows that, conditional on pooling, the high quality monopolist strictly prefers *any* test type to not having her new product tested at all before launch.

4.4 Choice of test toughness

Our second result shows that, despite being able to select from a continuum of test types, the monopolist is better off choosing either the softest possible public test or the toughest

[6] After passing the toughest test, maximal revenue equals one at price one since $\pi'_P = 1$ for all π: maximizing $\pi'_d(1 - G(\pi))$ in (6) by setting $\pi = \underline{\pi}$ returns this revenue. The high quality monopolist never fails the softest test; hence the maximization problem is not relevant for that case.

possible public test. The toughest test is sometimes best even though in our framework the monopolist cannot use the choice of a tough test to signal quality directly. The proof works by showing convexity of the high quality monopolist's expected revenue.

Lemma 1. *The high quality monopolist's expected revenue, given by (7), is convex in the toughness of the test* τ*.*

Consumers' Bayesian updating gives rise to posterior beliefs in the event of a pass that increase convexly in test toughness (note that $\frac{q_1^P}{q_0^P} = \frac{1-\tau}{1-\tau-\kappa}$, the ratio of the probability of passing conditional on the product being of high quality to the probability of passing conditional on low quality, increases convexly in test toughness τ). The monopolist's pricing flexibility allows her to take advantage of this convexity; hence revenue in the event of a pass increases faster and faster as the test becomes very tough, and falls more and more slowly as the test becomes very soft. Thus the probability of passing (which falls linearly in toughness) times maximal revenue in the event of a pass is also convex in test toughness. The other part of the revenue function arising from a test fail can also be shown to be convex, and summing over the pass and fail cases gives an overall expected revenue function that is convex. The convexity implies that, whatever the level of test expertise κ, the monopolist always prefers either the softest possible public test ($\tau = 0$) or the toughest possible public test ($\tau = 1 - \kappa$).[7]

Proposition 2. *For any level of test expertise, the monopolist always selects either the toughest public test or the softest public test.*

When choosing which test to face before launching her new product on the market, the monopolist faces a clear trade-off. On the one hand selecting a tougher test reduces the probability of passing. On the other hand, because consumers understand that a tougher test is more strongly biased against the product, a tougher test has a stronger positive impact on consumers' posterior beliefs in the event of a pass and a smaller negative impact in the event of a fail. The monopolist's pricing flexibility allows her to set an optimal price given the post-test distribution of posterior consumer beliefs: this bolsters the strong positive impact of passing a tough test and mitigates the strong negative impact of failing a soft test, and pushes the monopolist towards either the toughest or softest possible test.

[7] We can also consider what happens if κ is not fixed but rather is a choice variable that is constrained to lie within $[\underline{\kappa}, \overline{\kappa}]$, where $0 < \underline{\kappa} < \overline{\kappa} < 1$. In that case, Proposition 2 continues to hold in the sense that the monopolist will continue to always select either the toughest or softest public test.

The convexity of revenue in test toughness implies that Proposition 2 extends to the case where the monopolist cannot choose from the whole continuum of test types but must instead select from a restricted subset of tests: if the monopolist has to choose the toughness of the public test from a restricted and/or discrete set, she continues to select either the toughest test or the softest test in the available set.[8] This corollary tells us that the optimality of the toughest or softest available public test is not driven by the extreme nature of the optimal test in Proposition 2. The corollary also extends the applicability of our findings to realistic scenarios in which a full continuum of test types is not always available.

4.5 Pairwise comparison

We have just seen that, before launching her new product on the market, the monopolist always chooses either the toughest or softest public test. For any particular level of test expertise κ and distribution of private beliefs conditional on high quality $G(\pi)$, using (7) a pairwise comparison of expected revenues determines whether the toughest or softest test is best. To maintain generality we have imposed no structure on the distribution of private beliefs, and hence we cannot in general discover which of the two tests is best. Nonetheless, we are able to determine the optimal choice when the consumers' private signals are sufficiently informative or uninformative.

We now suppose that before receiving their private signals the consumers share a common prior belief γ about the probability that the product is of high quality. A common prior belief is a standard assumption in models of observational learning (see, for instance, [27]). We also assume that the lower bound on the consumers' private beliefs $\underline{\pi} < \frac{1}{2}$ and that the upper bound on private beliefs $\overline{\pi} > \frac{1}{2}$, and we denote the mean private belief by μ. We say that the private signals become *more informative* as the mean private belief μ rises towards $\overline{\pi}$ conditional on the product being of high quality and falls towards $\underline{\pi}$ conditional on the product being of low quality. We say that the private signals become *less informative* as the mean private belief μ tends towards the common prior belief γ and the variance of the private beliefs falls towards zero. The following proposition describes the optimal choice of test toughness when private signals are sufficiently informative or

[8]Suppose the monopolist has to choose test toughness $\tau \in [\underline{\tau}, \overline{\tau}]$ with $\underline{\tau} \geq 0$ and $\overline{\tau} \leq 1 - \kappa$. The proof of Proposition 2 continues to work, replacing the lower bound $\tau = 0$ with $\underline{\tau}$ and the upper bound $\tau = 1 - \kappa$ with $\overline{\tau}$, and letting interior τ lie in $(\underline{\tau}, \overline{\tau})$. If we replace $[\underline{\tau}, \overline{\tau}]$ with a discrete set with the same end points, the strict preference for the toughest or softest test in the set must remain.

uninformative.

Proposition 3.

(a) When the consumers' private signals become sufficiently informative, the monopolist selects the softest public test.

(b) When the consumers' private signals become sufficiently uninformative, the monopolist: (i) selects the toughest public test if the prior belief $\gamma < \frac{1}{2}$*; and (ii) selects the softest public test if the prior belief* $\gamma > \frac{1}{2}$*.*

The advantage of the softest test is the high probability of passing, while the advantage of the toughest test is the strong positive impact of a pass on consumers' posterior beliefs, and hence on revenue given the monopolist's ability to condition price on the test result. When consumers' private signals are uninformative and the consumers start with an unfavorable prior about product quality (case b.i), the monopolist values the big upward impact on beliefs from passing the toughest possible test. This might correspond to an innovative product about which consumers receive little private information: by choosing the toughest test the monopolist attempts to launch such a new product with a "baptism of fire".

When instead consumers' private signals are very informative (case a), or the private signals are uninformative but the consumers start with a favorable prior (case b.ii), the high quality monopolist understands that the consumers will tend to hold favorable private beliefs about quality before observing the test result (remember from Section 4.1 that we are considering the choice of the high quality monopolist, conditional on pooling). Thus there is little upside from risking the toughest test since the scope for beliefs to rise is limited; instead the monopolist plumps for the softest public test possible. This might correspond to a well-known type of product about which consumers receive clear private signals or towards which the consumers are positively predisposed.

5 Applications and discussion

Although we couch our model in terms of a monopolist launching a new product, our framework applies more broadly to situations in which a principal attempts to receive endorsements from a group of agents. For our framework to apply, the principal must be able to seek an outside test of quality (such as a review or certification decision), potential tests must vary in their toughness and the principal must be able to adjust the "price" of endorsement to the test result. Examples described by [17] include the sponsor of a new technology attempting to receive certification from standard-setting organizations ranging from fully independent to largely captive or an issuer of stocks or bonds seeking to be certified by investment banks and rating agencies which differ in their reputation and independence, where "price" is measured by the terms offered to end users or investors. Below we describe in more detail two applications of our model, the first to a standard monopoly firm context and the second to a politician seeking election. Of course, as is the case for all models, we do not capture every feature of reality; in particular, we abstract from the use of pre-launch reviews to increase awareness of a new product, from any competition between products and from the use of multiple testing opportunities (although our model does apply to the final such opportunity by incorporating previous test decisions in the consumers' private beliefs). Nonetheless, we believe that our results provide insights relevant to the examples described below.

Our first application focuses on the computer software industry, in which companies often approach magazines or websites to preview new releases. These magazines or websites typically have a known toughness: for example, video games websites often list the results of previews and give some indication of the reviewer's toughness. The outcome of previews affects sales (particularly in the pre-order market) and prices. Microsoft provides a particularly interesting case study. In 2009, Microsoft chose to launch Windows 7 with a very soft test: initially all information about Windows 7 came through official Microsoft sources, followed by an early preview (two months prior to the release of the beta version) by Paul Thurrott, the well-known pro-Microsoft blogger (on his website "SuperSite for Windows") and editor of Windows IT Pro Magazine. This case seems to match the assumptions of Proposition 3.a quite well: Windows 7 was similar to earlier well-known versions of the Windows operating system; hence it seems reasonable to assume that the potential market had accurate private information about its quality. In contrast, Microsoft selected a very tough test when in 2003 it launched a PC version of the hit Xbox game "Halo" developed in collaboration with Gearbox Software: the popular review site GameSpy was invited to preview the PC version of the game, even though GameSpy was one of the few review sites that did not award the original Xbox version of Halo near perfect marks (in fact GameSpy listed the Xbox version as one of the "25 most overrated games of all time"). This case seems to match the assumptions of Proposition 3.b.i quite well since PC owners who might consider buying the game likely had weak private information concerning its quality. First, most of the the potential market would not have owned the Xbox version. Second, the original Xbox version was developed by a different company, Bungie, and hence Gearbox's ability to convert successfully the game for the PC was in doubt.

Our second application considers politicians seeking election. Should such a politician face a soft test by interviewing with a media outlet sharing similar political leanings, or should the politician instead face a tough test by agreeing to a challenging interview with a media outlet from the opposite side of the political spectrum? After facing such a test, the politician can raise or lower the "price" of endorsement for undecided centrist voters by moving her policy position further away from or toward the center. The decision by the 2008 Republican vice-presidential candidate Sarah Palin to agree to an exclusive interview with Katie Couric at CBS, a station with a known bias to the left of Palin's own leanings, provides an interesting case study. Sarah Palin was picked by John McCain as his running mate from the relative obscurity of the Governorship of Alaska. As such, undecided centrist voters likely had weak private information about her qualities, making a tough test attractive. In the event, the interview on September 24th 2008 was widely acknowledged to be a failure throughout the media: the risk did not pay off. Even among the conservative media the feeling was negative: National Review editor Rich Lowry called Palin's performance "dreadful" (National Review, September 27th 2008), while former Republican presidential candidate Mike Huckabee stated that "It was not a good interview. I'm being charitable" (Esquire magazine, January 14th 2009). Nevertheless, in the light of poor polling through September, choosing to be interviewed by CBS may well have been the correct action even though in hindsight it went badly.

6 Conclusion

In this paper we provide an integration of two key choices for a monopolist hoping to convince consumers that she is offering a product worth buying: the choice of price, and the use of public testing as an early marketing strategy. Quite apart from any standard signaling arguments, we have found that a monopolist will tend to choose tests that are publicly known to be extremely tough or soft. Despite tough tests being difficult to pass, the tremendous gains when a pass is obtained might be enough to make them popular.

On the other hand, we can also better understand the popularity of friendly referees, soft review journals or easy reviewers. Avoiding the testing process altogether is not optimal; hence testing is a complement to optimal pricing.

Finally, we do not wish to draw attention away from other reasons to be tested (such as to provide factual information about the product and its imminent launch) or other possible methods to signal quality (such as a commitment to a low price if the demand is low, offering guarantees of product quality where this is cheaply verifiable, etc.). Future work might examine the interaction between these motivations and methods and those detailed in this paper.

Appendix

Proof of Proposition 1. Remember from Section 4.1 that we consider the high quality monopolist's choice of test and price, conditional on pooling. Let $\pi^* \in [\underline{\pi}, \overline{\pi}]$ maximize $\pi(1 - G(\pi))$, and therefore from (8) π^* is an optimal price for a high quality monopolist who chooses not to be tested. Clearly, $\pi^*(1 - G(\pi^*)) > 0$. Suppose that the monopolist chooses to be tested and that, conditional on the test decision d, she must set a price p at the posterior belief of a consumer with private belief π^*. Adapting (7), her expected revenue would be given by:[9]

$$R = \sum_{\mathbb{D}} \frac{\left(q_1^d\right)^2 \pi^*(1-G(\pi^*))}{q_1^d \pi^* + q_0^d (1-\pi^*)}. \tag{9}$$

Using (1) and $q_v^d \geq 0$, and since $\pi^* \in (0, 1)$ given the bounds on private beliefs, both denominators in (9) are strictly positive. Furthermore, $q_v^F = 1 - q_v^P$. Thus, for any test toughness, this revenue is strictly greater than $\pi^*(1 - G(\pi^*))$, the revenue of the monopolist who chooses not to be tested, if and only if:

$$\left(q_1^P\right)^2 \left(\left(1 - q_1^P\right) \pi^* + \left(1 - q_0^P\right)(1 - \pi^*)\right) + \left(1 - q_1^P\right)^2 \left(q_1^P \pi^* + q_0^P (1 - \pi^*)\right) > \tag{10}$$
$$q_1^P \left(1 - q_1^P\right) (\pi^*)^2 + q_0^P \left(1 - q_0^P\right) (1 - \pi^*)^2 + \left(q_1^P \left(1 - q_0^P\right) + q_0^P \left(1 - q_1^P\right)\right) \pi^* (1 - \pi^*). \tag{11}$$

Re-arranging, this collapses to $\left(q_1^P - q_0^P\right)^2 (1 - \pi^*)^2 > 0$. From (1), $q_1^P - q_0^P > 0$. Also, $\pi^* \in (0, 1)$ from above. Thus, when her pricing flexibility is restricted, the high quality monopolist strictly prefers any test toughness to not being tested. She therefore also strictly prefers any test toughness when she can set an optimal price, which in turn implies that she must strictly prefer to be tested when she can choose an optimal test toughness and price. ■

Proof of Lemma 1. We start by showing that

$$\frac{\left(q_1^d\right)^2 \pi(1-G(\pi))}{q_1^d \pi + q_0^d (1-\pi)} \tag{12}$$

[9] Under the toughest test, this expression understates revenue since when such a test is passed, the monopolist will sell to all consumers at $p = \pi'_P = 1$, rather than to a proportion $1-G(\pi^*)$ (see footnote 6); the argument is unaffected since we show that even this lower revenue beats the revenue from not being tested.

is always convex in test toughness τ. Using (4) and (5):

$$\frac{\left(q_1^P\right)^2\pi(1-G(\pi))}{q_1^P\pi+q_0^P(1-\pi)} = \frac{(1-\tau)^2\pi(1-G(\pi))}{(1-\tau)\pi+(1-\tau-\kappa)(1-\pi)} = \frac{(1-\tau)^2\pi(1-G(\pi))}{(1-\tau)-\kappa(1-\pi)}; \tag{13}$$

$$\frac{\left(q_1^F\right)^2\pi(1-G(\pi))}{q_1^F\pi+q_0^F(1-\pi)} = \frac{\tau^2\pi(1-G(\pi))}{\tau\pi+(\tau+\kappa)(1-\pi)} = \frac{\tau^2\pi(1-G(\pi))}{\tau+\kappa(1-\pi)}. \tag{14}$$

Given (1) and $1-\tau \geq \kappa$ (from $\tau \in [0, 1-\kappa]$), and since $\pi \in (0,1)$ given the bounds on private beliefs, the denominators of (13) and (14) are always strictly positive and the second derivatives of (13) and (14) with respect to τ are, respectively:[10]

$$\frac{2\kappa^2(1-\pi)^2\pi(1-G(\pi))}{((1-\tau)-\kappa(1-\pi))^3} \geq 0 \quad \text{and} \quad \frac{2\kappa^2(1-\pi)^2\pi(1-G(\pi))}{(\tau+\kappa(1-\pi))^3} \geq 0. \tag{15}$$

Note that (12) is continuous in π; hence at least one $\pi \in [\underline{\pi}, \overline{\pi}]$ must maximize (12). The maximum of convex functions is convex, as is their sum; hence the convexity of (12) implies that the high quality monopolist's expected revenue (7) is also convex in test toughness τ. ■

Proof of Proposition 2. Remember from Section 4.1 that we consider the high quality monopolist's choice of test and price, conditional on pooling. Lemma 1 implies that the high quality monopolist must weakly prefer either the toughest test ($\tau = 1-\kappa$) or the softest test ($\tau = 0$), or both, to any other test toughness.

We can show a strict preference by proving that starting from any interior $\tau \in (0, 1-\kappa)$ the monopolist could increase expected revenue. Let $\pi^*(\tau, d)$ be a $\pi \in [\underline{\pi}, \overline{\pi}]$ which maximizes (12) given a test toughness τ and test decision d, and let $\widetilde{\tau}$ be a particular interior τ. If the monopolist moved τ to another interior value away from $\widetilde{\tau}$, but, conditional on the test decision d, set price p at the posterior belief of a consumer with private belief $\pi^*(\widetilde{\tau}, d)$, adapting (7) her expected revenue would be given by:

$$\sum_{\mathbb{D}} \frac{\left(q_1^d\right)^2\pi^*(\widetilde{\tau},d)(1-G(\pi^*(\widetilde{\tau},d)))}{q_1^d\pi^*(\widetilde{\tau},d)+q_0^d(1-\pi^*(\widetilde{\tau},d))}. \tag{16}$$

The discussion around (4) and (5) shows that, unless $\tau = 0$, a consumer's posterior belief $\pi'_d = \frac{q_1^d\pi}{q_1^d\pi+q_0^d(1-\pi)} > 0$ for all private beliefs $\pi \in [\underline{\pi}, \overline{\pi}]$. Thus $\pi^*(\widetilde{\tau}, d) < \overline{\pi}$: any $\pi < \overline{\pi}$ gives revenue $\pi'_d(1-G(\pi)) > 0$, since then $G(\pi) < 1$, while $\pi = \overline{\pi}$ gives $\pi'_d(1-G(\pi)) = 0$, since $G(\overline{\pi}) = 1$. Note further that when $\pi < \overline{\pi}$, so that $G(\pi) < 1$, the second derivatives in (15)

[10] To find the second derivative of (14), note that the second derivative of $\frac{\tau^2}{\tau+x}$ with respect to τ is $\frac{2x^2}{(\tau+x)^3}$. The second derivative of (13) can then be derived immediately, noting that the second derivative of $\frac{(1-\tau)^2}{(1-\tau)+x}$ with respect to τ must equal the second derivative with respect to $1-\tau$.

are strictly positive (recall that $\kappa > 0$, $\pi \in (0,1)$ and $1-\tau \geq \kappa$), and hence (12) is strictly convex in τ. Given $\pi^*(\widetilde{\tau}, d) < \overline{\pi}$, this strict convexity implies that (16) is strictly convex in τ. Restricting her pricing flexibility, the monopolist could therefore strictly increase expected revenue by moving τ in an appropriate direction; therefore she must be able to increase revenue when she can set an optimal price. ■

Proof of Proposition 3. We split the proof into three parts. First, we state and prove Lemma 2. We then use the lemma to prove parts (a) and (b) in turn.

Lemma 2. *As the variance of the consumers' private beliefs tends to zero and the mean private belief tends to some value $\widehat{\mu}$, in the limit the monopolist selects the toughest test if $\widehat{\mu} < \frac{1}{2}$ and selects the softest test if $\widehat{\mu} > \frac{1}{2}$.*

Part 1: Proof of Lemma 2. Remember from Section 4.1 that we consider the high quality monopolist's choice, conditional on pooling. If the high quality monopolist chooses the softest test ($\tau = 0$), she passes the test for sure ($q_1^P = 1 - \tau = 1$); hence using (4) and (6) her maximal revenue is given by:

$$R(\tau = 0) = \max_{\pi} \tfrac{\pi}{\pi + (1-\kappa)(1-\pi)}(1 - G(\pi)). \tag{17}$$

If she chooses the toughest test ($\tau = 1 - \kappa$), with probability $q_1^P = 1 - \tau = \kappa$ she passes the test, in which case from (4) all consumers share a posterior belief $\pi'_P = 1$ since they are convinced the product is of high quality; hence maximal revenue equals one at price one. With probability $1 - \kappa$ the monopolist fails the test. Using (5) and (6) her expected revenue is therefore given by:

$$R(\tau = 1 - \kappa) = \kappa + (1 - \kappa) \max_{\pi} \tfrac{(1-\kappa)\pi}{(1-\kappa)\pi + (1-\pi)}(1 - G(\pi)). \tag{18}$$

As the variance of π in $G(\pi)$ tends to zero and its mean tends to $\widehat{\mu} \in [\underline{\pi}, \overline{\pi}]$, $G(\pi) \to 0$ for all $\pi < \widehat{\mu}$. Thus in the limit, after passing the softest test or failing the toughest test, the monopolist can achieve revenue arbitrarily close to that from selling to all consumers at price equal to the posterior of a consumer with private belief $\pi = \widehat{\mu}$ by setting price just below this level (or at this level if $\widehat{\mu} = \underline{\pi}$). The monopolist cannot do better than this: in the limit, for any $\pi > \widehat{\mu}$ the proportion of consumers purchasing goes to zero. Thus,

$$\kappa + \tfrac{(1-\kappa)^2\widehat{\mu}}{(1-\kappa)\widehat{\mu} + (1-\widehat{\mu})} \gtrless \tfrac{\widehat{\mu}}{\widehat{\mu} + (1-\kappa)(1-\widehat{\mu})} \tag{19}$$

implies that, in the limit, $R(\tau = 1 - \kappa) \gtrless R(\tau = 0)$. From Section 3, $\kappa \in (0,1)$, and

$\widehat{\mu} \in (0,1)$ given the bounds on private beliefs. Some algebra then shows that

$$(19) \;\Leftrightarrow\; \kappa(1-\kappa)(1-\widehat{\mu})(1-2\widehat{\mu}) \gtrless 0 \;\Leftrightarrow\; \widehat{\mu} \lessgtr \tfrac{1}{2}, \tag{20}$$

giving the lemma. □

Part 2: Proof Proposition 3(a). When the consumers' private signals become sufficiently informative, by definition the mean private belief tends to $\overline{\pi}$, which implies that the variance of the beliefs tends to zero. Thus, the result follows immediately from Lemma 2 given $\overline{\pi} > \frac{1}{2}$. □

Part 3: Proof of Proposition 3(b). When the consumers' private signals become sufficiently uninformative, by definition the mean private belief tends to the common prior belief and the variance of the beliefs tends to zero. Thus, the result follows immediately from Lemma 2. □ ■

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