The Optimal Choice of Pre-Launch Reviewer*

David Gill†, Daniel Sgroi‡

September 21, 2010

PRELIMINARY AND INCOMPLETE

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 strong positive impact on consumer beliefs of passing a tough test and mitigates the strong 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: tests, reviewers, certification, Bayesian learning, information transmission, marketing, product launch, bias, tough test, soft test.

JEL Classification: D82, D83, L15.

*David Gill would like to thank Trinity College, Oxford, where this research was initiated. Daniel Sgroi would like to thank the Leverhulme Trust for financial support.

†Division of Economics, University of Southampton, d.gill@soton.ac.uk

‡Department of Economics, University of Warwick, daniel.sgroi@warwick.ac.uk

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?[1] Should a film-maker choose to premiere his movie at a prestigious film festival such as Cannes, where competition for prizes is fierce, or at a less well known festival with weaker competitors?

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 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. As a result, all our equilibria will be pooling so the firm cannot use the choice of test or price to signal her product quality directly. Thus our framework rules out Spence (1973)-style signaling, which was studied by Hvide (2009) in the context of a model with certification fees and two types of test. 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 firm chooses the toughest possible test to maximize the impact of passing the test. In that

[1] See Lerner and Tirole (2006), p. 1091, for a description of bias in technology standard setters.

case, the firm 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

Remarkably, the literature has paid almost no attention to the use of public tests to transmit information, especially when used in combination with price. A small literature analyzes the use of initial prices to manipulate sales in a learning environment. For example, Taylor (1999) and Bose et al. (2007, 2008) find that high initial prices, whose effects are similar to the choice of a tough test, can be optimal, though in Bose et al. the firm does not know its own quality. By contrast, in Caminal and Vives (1996, 1999), in which early prices are unobservable to later consumers, and in Welch (1992), in which prices cannot be conditioned on the history of purchases, low introductory prices are optimal.

Lerner and Tirole's (2006) paper focuses on the role of technology standard setting authorities as certifiers, Chiao, Lerner and Tirole (2007) empirically test Lerner and Tirole's model, while Farhi, Lerner and Tirole (2005) extend the model to a dynamic setting. Similarly to our tests, the certifiers have an arbitrary bias towards the technology sponsor which determines their decision rule, however unlike in our paper the sponsor 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 review; consumers do not receive any private information; and there is no incentive to set price in response to the certification (as the certifier's endorsement rule is sensitive to any anticipated price response to its decision). Therefore, as certifiers cannot counter bad private information or enable a rise in price, Lerner and Tirole find no role for certifiers biased against the technology.

Gill and Sgroi (2008) look at a similar problem to ours, but essentially consider fixed prices in the context of a sequential endorsement model with a special signal structure. We allow price flexibility and thereby examine the interplay between test choice and optimal price, finding that

this interplay is extremely important, generating convexity in the monopolist's revenue function and driving test choices to an extreme. This completely overturns the main result in Gill and Sgroi (2008) that a very slightly tough test is best. Moreover, as the length of the sequence of agents in Gill and Sgroi (2008) tends to one, that model can be re-interpreted as a highly simplified analogue of the model in this paper. The key "simplification" concerns the special binary nature of consumers' signals in Gill and Sgroi (2008) which allows a test to be chosen that is "just" tough enough to induce those consumers with low beliefs to purchase. We can then reinterpret the results in Gill and Sgroi (2008) as driven by the monopolist's inability to increase price after passing a very tough test, so lessening the usefulness of very tough tests as opposed to marginally tough tests.

In Sgroi (2002) and Callander and Hörner (2009), multiple public decisions made by consumers at the start of a product's life-cycle act in a similar way to a public test. Callander and Hörner provide conditions under which a minority of earlier customers adopting can act as a stronger signal of quality than when a majority do. Sgroi (2002) finds that a firm (or social planner) should optimally select to use early decision makers to boost sales (or welfare) which provides an antecedent for our result that a public test should always be used, but Sgroi (2002) has neither prices nor a notion of toughness, so can offer no guide as to optimal toughness or any discussion of the interaction with prices.

3 Model

Payoffs. 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 (so we don't have a game persuasion *à* la Milgrom, 1981), and aims to maximize expected revenue.

Private Beliefs. Each consumer receives a private signal about product quality and forms a private belief π about the probability that the product is of high quality. Conditional on quality v, the private signals are i.i.d., leading to a continuous quality-dependent cumulative distribution function $F_v(\pi)$ with support $[\underline{\pi}, \overline{\pi}]$ over the consumers' beliefs which is known to the monopolist. We assume that $\underline{\pi} > 0$ and $\overline{\pi} < 1$, so the beliefs are bounded and thus no private signal perfectly reveals quality. Our formulation places no 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.

Tests. The monopolist chooses whether or not to subject herself to a public test or review. 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.[2] The probability of decision d given quality v is given by $q_v^d \in [0,1]$,[3] with $\sum_{\mathbb{D}} q_v^d = 1$, which implies that $q_1^P - q_0^P = q_0^F - q_1^F$. To ensure that a pass is good news about product quality and that a fail is bad news, we assume that

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

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. 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 so the monopolist does not face a choice of toughness.

Pricing Decision. 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.

Purchasing Decisions. After observing the choice of test τ, the test's decision d (if $\tau \neq N$) and the chosen price p, each consumer forms a posterior belief π' about the probability that the product is of high quality. As each consumer is risk neutral, this posterior belief equals the consumer's expected utility from purchasing net of the price, so the consumer buys if and only if $\pi' \geq p$. The consumers make their purchasing decisions simultaneously.

Pooling Equilibria. We have a game of imperfect information, so we solve for perfect Bayesian equilibria, and we restrict attention to pure strategies. All equilibria must be pooling. Suppose not: in a non-pooling 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, thereby ensuring that all consumers believed her product to be of high quality for sure.

Consumers' Posterior Beliefs. As the equilibria are pooling, the monopolist is unable to signal her product quality via the choice of test τ and price p per se. A key modeling distinction between or model and models which follow Spence (1973) is that the cost of being tested is not a function of the type of the monopolist. In Spence (1973) the level of education is a useful discriminator because it is more costly for a low quality type to be educated than the high quality

[2]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 Calvert (1985), Sah and Stiglitz (1986) and Lerner and Tirole (2006). As Calvert (1985, p. 534) puts it: "This feature represents the basic nature of advice, a distillation of complex reality into a simple recommendation."

[3]Conditional on quality, the private signals are independent of the test decision.

type, but in our model the direct cost of using any tester is zero for both types. Moreover, if either type could convince consumers that they were the high quality type for certain by selecting an arbitrary test toughness, then they would make the maximum possible revenue (normalized to 1 in our model). Thus we focus attention on the direct role of the test itself in transmitting information to the consumers, who learn only from the test decision d, rather than the use of test toughness as a signal in itself.[4] If the monopolist chooses to be tested, using Bayes' Rule the posterior belief of a consumer with private belief $\pi \in [\underline{\pi}, \overline{\pi}]$ after observing a test decision d is given by:

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

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

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

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

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

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

Restriction to High Quality Monopolist's Choice. 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 price p. Under this assumption, in equilibrium a low quality monopolist is forced to follow a high quality monopolist's choice of test τ and conditional pricing rule or reveal her type to be low. Note that although failing the softest test reveals a low quality monopolist's type, she still has some chance of passing such a test whereas deviating from the pooling equilibrium would reveal her type as low quality for certain.

High Quality Monopolist's Revenue Function. After a test decision d, the monopolist can sell to the proportion of consumers $1 - F_v(\pi)$ whose private beliefs are at least as good as $\pi \in [\underline{\pi}, \overline{\pi}]$ by setting price p equal to the posterior belief π' of a consumer whose private belief exactly equals π. Thus, conditional on the test decision d, maximal revenue for a high quality

[4]For simplicity, we do not consider mixed strategy equilibria; however, if we allowed mixed strategies, the consumers would continue to learn only from the test's decision d. Just as for separating equilibria, semi-separating equilibria in which one type of monopolist mixed and the other did not at a particular choice would be ruled out.

monopolist is given by:[5]

$$\max_{\pi} \pi'(1 - F_1(\pi)) = \max_{\pi} \frac{q_1^d \pi}{q_1^d \pi + q_0^d (1 - \pi)} (1 - F_1(\pi)). \tag{6}$$

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:

$$R = \sum_{\mathbb{D}} q_1^d \max_{\pi} \frac{q_1^d \pi}{q_1^d \pi + q_0^d (1 - \pi)} (1 - F_1(\pi)) = \sum_{\mathbb{D}} \max_{\pi} \frac{\left(q_1^d\right)^2 \pi (1 - F_1(\pi))}{q_1^d \pi + q_0^d (1 - \pi)}. \tag{7}$$

If the high quality monopolist chooses not to be tested, $\pi' = \pi$ so she will sell to a proportion $1 - F_1(\pi)$ of consumers by setting price $p = \pi$. Thus her maximal revenue is given by:

$$R = \max_{\pi} \pi (1 - F_1(\pi)). \tag{8}$$

4 Results

4.1 Choosing to be Tested

Our first result is that the monopolist will always opt to have her new product tested publicly before launch; in fact *any* test is better than not facing a public test at all.

Proposition 1. *The monopolist strictly prefers a public test of any toughness to not having her new product tested at all before launch.*

The result is intuitive. In expectation, a test reveals good information about a high quality product, so 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. The proof works by restricting the monopolist to choosing a conditional price to target the same proportion of consumers as would be targeted in the absence of a test and showing that, even under this restriction on pricing, the principal prefers any given test to not being tested. *A fortiori* she prefers to be tested in the absence of this restriction.

4.2 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 selecting either the softest possible public test ($\tau = 0$) or the toughest possible public test ($\tau = 1 - \kappa$). The result holds true whatever the level of test expertise κ.

[5] After passing the toughest test, maximal revenue is one at price one as $\pi' = 1$ for all π: maximizing $\pi'(1 - F_1(\pi))$ in (6) by setting $\pi = \underline{\pi}$ returns this revenue. The high quality monopolist never fails the softest test, so the maximization problem is not relevant for that case.

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.

Proposition 2. *For any level of test expertise, the monopolist always strictly prefers either the toughest public test or the softest public test (or both) to any other test toughness.*

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.

The proof works by showing that the monopolist's expected revenue, given by (7), is convex in test toughness. Consumers' Bayesian updating entails that their posterior beliefs in the event of a pass increase convexly in test toughness (note that $\frac{1-\tau}{1-\tau-\kappa}$, 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, so 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 shown to be convex, and summing over the pass and fail cases gives an overall expected revenue function that is convex.[6]

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.

Corollary to Proposition 2. *If the monopolist has to choose the toughness of the public test from a restricted and/or discrete set, she continues to strictly prefer either the toughest test or the softest test in the available set.*

This corollary tells us that there is nothing special about the toughest or softest conceivable tests which pushes the monopolist to make an extreme choice. The corollary also extends the

[6]This convexity is reminiscent of the findings in Johnson and Myatt (2006) and Lewis and Sappington (1994) that a monopolist's profit is convex in the amount of information released to consumers, so 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 as 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 so are learning about objective quality. The tougher the test, the more demand shifts out after a pass and the less it shifts in after a fail.

applicability of our findings to realistic scenarios in which a full continuum of test types is not always available.

4.3 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 $F_1(\pi)$, using (7) a pairwise comparison of expected revenues determines whether the toughest or softest test is best. As we have imposed no structure on the distribution of private beliefs, 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, Smith and Sorensen, 2000). 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 uninformative.

Proposition 3.

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

(b) When the consumers' private signals become sufficiently uninformative, the monopolist: (i) strictly prefers the toughest public test if the prior belief $\gamma < \frac{1}{2}$; and (ii) strictly prefers 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 monopolist understands that the consumers will tend to hold favorable private beliefs about quality before observing the test result (remember that we are considering the choice of the high quality monopolist, conditional on pooling). Thus there is little upside from risking the toughest test as 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

[Incomplete]

Our's is a partial equilibrium model and as such will never capture everything from the real world. For instance, one reason to seek a pre-launch review which we do not cover is to increase awareness of a new product. In practice the rationale in our model will combine with other rationales to produce a complex picture, which makes it all the more surprising that our model can capture *some* of the key elements from the real world. Moreover, in order to keep things simple we have made assumptions that are unlikely to always hold. For instance, we discuss a monopolist while in practice there may be some alternative available. Our model requires that consumers are aware of test toughness which may not always hold. However, in some cases this is may be well-known or clear, in others reputation may be important or there may be sources which exist to inform consumers of alleged bias, for example www.stinkyjournalism.org for journalism or punditscale.com for US political pundits.

Perhaps the most straight-forward examples come from the certification industry and these are documented in the work of Fahri, Lerner and Tirole. In particular see footnote 26 in Lerner and Tirole (2006) for specifics on legal certification and the certification of business schools, while the paper in general focuses on certifying technology. Fahri, Lerner and Tirole (2008) also discuss entry-level examinations and rating agencies.[7] Rather than repeating their examples we will look at two very different situations designed to provide variety.

In our first case we focus on one company, Microsoft, and see that the same firm opted for different review toughness levels in different circumstances. Computer software companies often approach magazines or online sites to preview new releases. Web-sites and magazines typically have a known toughness. For example, general video games web-sites will often list not only the results of reviews and previews, but also give some indication of the reviewer's toughness, while magazines owned by the same company that produce a game or piece of software carry the label

[7] To give an example of varying toughness in product certification not mentioned in their work, in Europe, Red Book's BRE certification claims to be a more rigorous alternative to the much milder assessment provided by CE marking.

"official magazine" or "preferred reviewer" which indicates relative softness. Early success for software in a preview can have huge implications for the sales of the product, especially in the pre-order market and since previews are only made available at the behest of the producer and prices are flexible, our model applies. When Microsoft launched Windows Vista in November 2006, initially all information about the new operating system came through official Microsoft sources, followed by an exclusive preview by Paul Thurrot, the well-know pro-Microsoft blogger and editor of Windows IT Pro Magazine. A new Windows operating system is likely to be similar to previous ones and so it seems reasonable to assume that the potential market would have good private information. On that basis our model confirms that Microsoft should opt to send their new operating system for the softest available preview and should continue to make use of preferred reviewers and official sites. In a very different situation, Microsoft in collaboration with Gearbox Software developed a PC version of the hit Xbox game "Halo" in 2003. Gamespy was one of the few review sites that did not award the original Xbox version of Halo near perfect marks, and went on record saying they believed the original game wasn't quite as perfect as other critics made it out to be. Despite their tough reputation, Gearbox Software *invited* Gamespy to preview the PC version of the game in advance of its public release. Here, there are many reasons to believe that the potential market had very weak private information concerning the quality of the game. First, there had been no previous game in the Halo franchise for PC and so PC owners who might consider buying it were likely to have had only limited contact with the game (those who possessed the Xbox version would not be likely to be considered part of the potential market). Second, the original Xbox version of Halo was developed by a different company, Bungie, and not Gearbox Software, so the ability of this new company to faithfully convert the software was also in doubt. On that basis our model would suggest that Microsoft should welcome a preview by a known tough reviewer.

In our second example we might wonder why Republican vice-presidential candidate, Sarah Palin would agree to an exclusive interview with Katie Couric at CBS, a station with a known bias to the left of Palin's own leanings. Our model would suggest that this would make sense if the Republican ticket of McCain and Palin were polling poorly prior to the interview which maps to a low belief among voters in our model. Indeed this seemed to be the case. Initially the two parties were neck and neck but by the end of August 2008 every major poller was putting Obama's team ahead.[8] Even Palin's support among women was falling back according to CBS polls, which indicated a drop from 43% to 34% in the last two weeks prior to the interview. In the event, the interview on 24 September 2008 was widely acknowledged to be a failure throughout the media. Even among the conservative media the feeling was negative: National Review editor Rich Lowry called Palin's performance "dreadful"(National Review 27 September 2008) with even senior Republicans such as Steve Schmidt, McCain's senior campaign

[8]See http://www.realclearpolitics.com.

strategist and advisor, and Mike Huckabee, former presidential candidate, admitting how poorly the interview went (in Townhall.com and Esquire Magazine respectively). 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. Looking at the polling figures, support for McCain/Palin did not collapse after the interview despite the supposed scale of the "failure" by Palin, but remained stable relative to earlier polls, which fits the notion of a tough test having a diminished impact in the event of a fail. Finally, our model requires that there is something akin to a "price" in politics: to this end we might consider the political spectrum. Knowing that die-hard Republicans are likely to vote Republican, by moving key policies towards the left McCain/Palin could lower the "price" to voters in the center, at the cost of having to mitigate their actions conditional on a win. Since the interview fits the notion of a tough test in our model, even failing the test would not require any great price reduction to mitigate the result, and indeed there is no evidence of any major move to the left to woo voters in the center.

6 Conclusion

The results in this paper provide an integration of two key choices for a monopolist (firm, job market candidate, politician) hoping to convince consumers (customers, employers, supporters) that she is offering a product that is high quality: the choice of a 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 whose product type is unknown to consumers will tend towards facing tests that are publicly known to be extremely tough or soft. We have seen that avoiding the testing process is not optimal, so testing is a complement to optimal pricing. After the test result is known, the monopolist can then select an optimal price, and consumers will purchase based on the price, test result, test type and their own private information. In many cases it is the toughest test that will be best for the monopolist in expectation despite this test being the hardest to pass. This would appear to consumers as though the monopolist is opting to put her product through a "baptism of fire", hoping for the powerful impact of passing a tough test. By enabling the monopolist to set a very high price following such a pass, the tough test increases expected revenue while keeping the impact of a fail to a minimum. This would be the best option if the private signals received by consumers are relatively uninformative, which might correspond to a very innovative product. Alternatively, if consumers receive relatively informative private signals, which might correspond to the launch of a well-known type of product, then the monopolist does not need to risk a tough test and instead chooses the softest test: garnering the support of a "yes-man" or subjecting herself to scrutiny from a body strongly biased in favor of her product.

Finally, we do not wish to draw attention away from other reasons to be tested (whether this

be to provide factual information about the product and its imminent launch, or for Spence-style signaling purposes) or the other methods available to signal quality (such as providing a commitment to low price if the demand is low, offering guarantees of product quality where this is cheaply verifiable, etc.). Future work might examine the interactions between these motivations and methods and those detailed in this paper.

Appendix

Proof of Proposition 1. Remember from Section 3 that we consider the high quality monopolist's choice of test and price, conditional on pooling. Let π^* be a $\pi \in [\underline{\pi}, \overline{\pi}]$ which maximizes $\pi(1 - F_1(\pi))$, and so from (8) is an optimal price for a high quality monopolist who chooses not to be tested. Clearly, $\pi^*((1 - F_1(\pi^*)) > 0$. 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]

$$R = \sum_{\mathbb{D}} \frac{\left(q_1^d\right)^2 \pi^* (1 - F_1(\pi^*))}{q_1^d \pi^* + q_0^d (1 - \pi^*)}. \tag{9}$$

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 $\pi^*(1 - F_1(\pi^*))$, 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 prefers any test toughness to not being tested. She must therefore also prefer to be tested when she can set an optimal price. ■

Proof of Proposition 2. We start by showing that

$$\frac{\left(q_1^d\right)^2 \pi (1 - F_1(\pi))}{q_1^d \pi + q_0^d (1 - \pi)}, \tag{12}$$

[9] Under the toughest test, this expression understates revenue as when such a test is passed, the monopolist will sell to all consumers at $p = \pi' = 1$, rather than to a proportion $1 - F_1(\pi^*)$ (see footnote 5); the argument is unaffected as we show that even this lower revenue beats the revenue from not being tested.

is always convex in test toughness t, and is strictly convex for $\pi < \overline{\pi}$. Using (4) and (5):

$$\frac{\left(q_1^P\right)^2\pi(1-F_1(\pi))}{q_1^P\pi+q_0^P(1-\pi)} = \frac{(1-\tau)^2\pi(1-F_1(\pi))}{(1-\tau)\pi+(1-\tau-\kappa)(1-\pi)} = \frac{(1-\tau)^2\pi(1-F_1(\pi))}{(1-\tau)-\kappa(1-\pi)}; \tag{13}$$

$$\frac{\left(q_1^F\right)^2\pi(1-F_1(\pi))}{q_1^F\pi+q_0^F(1-\pi)} = \frac{\tau^2\pi(1-F_1(\pi))}{\tau\pi+(\tau+\kappa)(1-\pi)} = \frac{\tau^2\pi(1-F_1(\pi))}{\tau+\kappa(1-\pi)}. \tag{14}$$

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

$$\frac{2\kappa^2(1-\pi)^2\pi(1-F_1(\pi))}{\left((1-\tau)-\kappa(1-\pi)\right)^3} \geq 0 \quad \text{and} \quad \frac{2\kappa^2(1-\pi)^2\pi(1-F_1(\pi))}{\left(\tau+\kappa(1-\pi)\right)^3} \geq 0. \tag{15}$$

When $\pi < \overline{\pi}$, so $F(\pi) > 0$, the second derivatives are strictly postive.

Remember from Section 3 that we consider the high quality monopolist's choice of test and price, conditional on pooling. Note that (12) is continuous in π, so at least one $\pi \in [\underline{\pi}, \overline{\pi}]$ must maximize (12). The maximum of convex functions is convex, as is their sum, so the convexity of (12) implies that expected revenue (7) is also convex in test toughness τ. Thus 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:

$$\sum_{\mathbb{D}} \frac{\left(q_1^d\right)^2\pi^*(\widetilde{\tau},d)(1-F_1(\pi^*(\widetilde{\tau},d)))}{q_1^d\pi^*(\widetilde{\tau},d)+q_0^d(1-\pi^*(\widetilde{\tau},d))}. \tag{16}$$

The discussion around (4) and (5) shows that, unless $\tau = 0$, a consumer's posterior belief $\pi' = \frac{q_1^d\pi}{q_1^d\pi+q_0^d(1-\pi)} > 0$ for all private beliefs $\pi \in [\underline{\pi}, \overline{\pi}]$. Thus $\pi^*(\widetilde{\tau}, d) < \overline{\pi}$: any $\pi < \overline{\pi}$ gives revenue $\pi'(1-F_1(\pi)) > 0$, while $\pi = \overline{\pi}$ gives $\pi'(1-F_1(\pi)) = 0$ as $F(\overline{\pi}) = 0$. The strict convexity of (12) for $\pi < \overline{\pi}$ found above then 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, and so she must be able to increase revenue when she can set an optimal price. ■

Proof of Corollary to Proposition 2. 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. ■

Proof of Proposition 3. We split the proof into three parts. First, we state and prove Lemma 1. We then use the lemma to prove parts (a) and (b) in turn.

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

Part 1: Proof of Lemma 1. Remember from Section 3 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 ($q_1^P = 1 - \tau = 1$), so using (4) and (6) her maximal revenue is given by:

$$R(\tau = 0) = \max_{\pi} \tfrac{\pi}{\pi + (1-\kappa)(1-\pi)}(1 - F_1(\pi)). \tag{17}$$

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 $\pi' = 1$ as they are convinced the product is of high quality, so maximal revenue is one at price one. With probability $1 - \kappa$ the monopolist fails the test. Using (5) and (6) her expected revenue is therefore given by:

$$R(\tau = 1 - \kappa) = \kappa + (1 - \kappa) \max_{\pi} \tfrac{(1-\kappa)\pi}{(1-\kappa)\pi + (1-\pi)}(1 - F_1(\pi)). \tag{18}$$

As the variance of π in $F_1(\pi)$ tends to zero and its mean tend to $\mu \in [\underline{\pi}, \overline{\pi}]$, $F_1(\pi) \to 0$ for all $\pi < \mu$. Thus, 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 $\pi = \mu$ by setting π just below μ. The monopolist cannot do better than this: in the limit, for any $\pi > \mu$ the proportion of consumers purchasing goes to zero and lowering price clearly cannot improve revenue. Thus,

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

implies that, in the limit, $R(\tau = 1 - \kappa) \gtrless R(\tau = 0)$. From Section 3, $\kappa \in (0, 1)$, and $\mu \in (0, 1)$ given the bounds on private beliefs. Some algebra then shows that

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

giving the lemma. □

Part 2: Proof Proposition 3(a). Remember from Section 3 that we consider the high quality monopolist's choice, conditional on pooling. Thus in the limit, as the private signals become sufficiently informative, the mean private belief μ tends to $\overline{\pi}$, which implies that the variance of the beliefs tends to zero. The result then follows immediately from Lemma 1 given $\overline{\pi} > \frac{1}{2}$. □

Part 3: Proof of Proposition 3(b). When the consumers' private signals become sufficiently uninformative, 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 1. □ ■

References

Bose, S., Orosel, G., Ottaviani, M. and Vesterlund, L. (2007) Dynamic Monopoly Pricing with Herding, RAND Journal of Economics, 37, 910-928.

Bose, S., Orosel, G., Ottaviani, M. and Vesterlund, L. (2008) Monopoly Pricing in the Binary Herding Model, Economic Theory, 37, 203-241.

Callander, S. and Hörner, J. (2009) The Wisdom of the Minority, Journal of Economic Theory, 144, 14211439.

Calvert, R. L. (1985) The Value of Biased Information: A Rational Choice Model of Political Advice, Journal of Politics, 47, 530-555.

Caminal, R. and Vives, X. (1996) Why Market Shares Matter: An Information-Based Theory, RAND Journal of Economics, 27, 221-239.

Caminal, R. and Vives, X. (1999) Price Dynamics and Consumer Learning, Journal of Economics and Management Strategy, 8, 95-131.

Chiao, B., Lerner, J. and Tirole, J. (2007) The Rules of Standard Setting Organizations: An Empirical Analysis, RAND Journal of Economics, 38, 905-930.

Farhi, E., Lerner, J. and Tirole J. (2005) Certifying New Technologies, Journal of the European Economic Association, 3, 734-744.

Gill, D. and Sgroi, D. (2008) Sequential Decisions with Tests, Games and Economic Behavior, 63, 663-678.

Hvide, H.K. (2009), Oligopolistic Certification, B.E. Journal of Theoretical Economics, 9(1), Topics, Art. 5.

Johnson, J.P. and Myatt, D.P. (2006), On the Simple Economics of Advertising, Marketing, and Product Design, American Economic Review, 96, 756-784.

Lerner, J. and Tirole, J. (2006) A Model of Forum Shopping, American Economic Review, 96, 1091-1113.

Milgrom, P. R. (1981), Good News and Bad News: Representation Theorems and Applications, Bell Journal of Economics, 12, 380-391.

Sah, R. K. and Stiglitz, J. E. (1986), The Architecture of Economic Systems: Hierarchies and Polyarchies, American Economic Review, 76, 716-727.

Sgroi, D. (2002) Optimizing Information in the Herd: Guinea Pigs, Profits and Welfare, Games and Economic Behavior, 39, 137-166.

Smith, L. and Sorensen, P. N. (2000) Pathological Outcomes of Observational Learning, Econometrica, 68(2), 371-398.

Spence, M. (1973) Job Market Signaling, Quarterly Journal of Economics, 87 (3), 355374.
Taylor, C. R. (1999) Time-on-the-Market as a Sign of Quality, Review of Economic Studies, 66, 555-578.

Welch, I. (1992) Sequential Sales, Learning, and Cascades, Journal of Finance, 47, 695-732.