

# Products Liability, Signaling and Disclosure

by

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We examine the behavior of a firm that produces a product with a privately-observed safety attribute. Costly disclosure and price-signaling of safety are alternative firm strategies. The liability system and production cost determine the firm's full marginal cost. When the firm's full marginal cost is increasing (decreasing) in safety, a firm with a safer product will distort its price upward (downward) and will sometimes inefficiently choose to signal rather than disclose (to disclose rather than signal). We also allow for a small fraction of naively optimistic (pessimistic) consumers; this leads to less price distortion and decreased (increased) incentives to disclose. (JEL: K 13, L 15, D 82)

## *1 Introduction*

In this paper we examine the behavior of a firm that produces a product with a safety attribute. We assume that the firm knows whether its product is of high safety or low safety (its "type"), where a safer product is one with a lower probability of causing harm. Consumers of the product cannot observe directly the product's safety, but they can learn safety through one of two routes. The firm may, at a cost, disclose its safety prior to sale; alternatively, if a firm does not disclose its safety then consumers can attempt to infer its safety from the price charged. That is, consumers may learn the product's safety through disclosure or through signaling.

The liability system is important because it is a determinant of the firm's full marginal cost, which consists of both manufacturing cost and liability cost; this dependence of marginal cost on liability in turn affects the price and the output level for the firm, thereby influencing welfare. In particular, if the firm does not bear substantial liability for a consumer's harm, then the firm's marginal cost consists mainly of manufacturing cost, which is presumably higher for safer products. On the other hand, if the firm does bear substantial liability for a consumer's harm, then the firm's marginal cost consists of both manufacturing cost and liability cost. In this case, it is quite possible for a firm producing a safer product to have lower full marginal cost (the composition of marginal cost and its relationship to liability law will be discussed in detail below). We show that

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whether high safety is signaled with a higher or a lower price (than would occur under full information) depends critically upon whether the firm bears substantial liability for a consumer's harm.<sup>1</sup>

Since the safety of a firm's product is revealed – either through disclosure or through signaling – a welfare analysis of voluntary disclosure now focuses not on how much information is ultimately revealed, *but whether it is revealed through the socially-optimal channel*. A low-safety type charges its full-information price and makes its full-information profits in a separating signaling equilibrium; consequently, a low-safety type will never engage in disclosure for any positive disclosure cost. When the firm does not bear substantial liability for a consumer's harm, then in a separating signaling equilibrium the high-safety type charges a higher price and sells less output than it would under full information (*a fortiori*, this is less than the socially-optimal output). Since the firm considers its own profit increase from disclosure, but not the value of the additional output to consumers, there will be a range of disclosure costs for which the high-safety type inefficiently chooses to signal rather than disclose. In this parameter regime a mandatory disclosure rule may be beneficial (this is discussed with more precision in section 4). However, when the firm does bear substantial liability for a consumer's harm, then in a separating signaling equilibrium the high-safety type typically<sup>2</sup> charges a *lower* price and sells *more* output than it would under full information (though still less than the socially-optimal output). In this case, although there is a range of disclosure costs for which the high-safety type will choose disclosure, any disclosure by the high-safety type is welfare-impairing, even if the disclosure cost is zero. Thus, whether *ex ante* information regulation (in the form of mandatory disclosure) or reliance on *ex post* liability that induces information revelation is the better policy also depends upon whether the firm faces substantial liability for a consumer's harm.

Finally, we re-consider the analysis under the assumption that a small fraction of consumers are “naive:” while these consumers become informed when safety is disclosed, they do not update their beliefs about safety based on the product's price (following nondisclosure). We first consider naively optimistic consumers, who persistently believe that the product is of high safety, and purchase accordingly. We find that the presence of such consumers is beneficial not only to the low-safety type, but also to the high-safety type (since it need not engage in as much distortion in order to signal its safety). Since both firm types enjoy higher profits in the separating signaling equilibrium, incentives for voluntary disclosure are reduced by the presence of optimistic consumers. In contrast, when the naive consumers are pessimistic (i.e., in the absence of disclosure they persistently believe that the product is of low safety and purchase accordingly), then the low-

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<sup>1</sup> Technically, when the firm's full marginal cost is increasing (decreasing) in safety, we find that the firm distorts its price upward (downward) to signal high safety. We showed this basic result for a continuum of types in DAUGHETY AND REINGANUM [1995], but that model did not allow for voluntary disclosure or for possibly-naive consumers.

<sup>2</sup> We say “typically” because when the marginal cost of a low-safety unit is substantially higher than the marginal cost of a high-safety unit, then the firm with the high-safety product can signal without distorting its price away from the full-information level.

safety type's signaling profits are unchanged but the high-safety type's signaling profits are diminished. Thus, incentives for voluntary disclosure are enhanced by the presence of naively pessimistic consumers.

### *1.1 Literature Review*

There is an extensive economics literature that deals with firms selling products whose quality is exogenous and known to the firms themselves, but is not observable to consumers prior to purchase.<sup>3</sup> Two alternative conceptualizations of the problem have yielded two streams of research between which, to our knowledge, there is virtually no cross-talk. The two resulting literatures are (1) the disclosure literature, which assumes that a firm can credibly disclose its quality, perhaps at a cost; and (2) the signaling literature, which assumes that a firm cannot credibly disclose its quality and must rely on other strategies, most notably the price, that might convey information. The disclosure literature invariably makes an assumption which renders signaling impossible: the marginal cost of production is independent of quality.<sup>4</sup> Thus, for these models, nondisclosure is consistent with all nondisclosing types charging the same price. For examples of models which involve a single firm (or can be viewed as such due to a lack of strategic interaction), see VISCUSI [1978], GROSSMAN [1981], MILGROM [1981], JOVANOVIC [1982], MATTHEWS AND POSTLEWAITE [1985], MILGROM AND ROBERTS [1986b], SHAVELL [1994] and POLINSKY AND SHAVELL [2006]. For examples involving multiple firms, see BOARD [2003], CHEONG AND KIM [2004], LEVIN, PECK, AND YE [2007], and HOTZ AND XIAO [2005].

Few signaling models of product quality assume that products of different quality are equally costly to produce (but see HERTZENDORF AND OVERGAARD [2001a], [2001b] for models that do make this assumption). Most signaling models assume that higher-quality products are more costly (examples include BAGWELL AND RIORDAN [1991], BAGWELL [1992], SHIEH [1993], FLUET AND GARELLA [2002], and DAUGHETY AND REINGANUM [2005], [2007a]), and some are agnostic on the issue, allowing higher-quality products to be either more or less costly (examples include MILGROM AND ROBERTS [1986a] and DAUGHETY AND REINGANUM [1995], [2005]). This difference in marginal costs allows the price chosen by the firm to reveal its product's quality.

Several previous papers develop models in which price signals product quality; such a model will appear as part of our analysis, but it will be augmented with a disclosure decision. BAGWELL AND RIORDAN [1991] provide a two-type model which is very similar to the one we use for our signaling subgame; the main difference is that we also allow full marginal cost to decrease in quality, which is envisioned in this paper as safety. DAUGHETY AND REINGANUM [1995] provide a

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<sup>3</sup> The case in which quality is endogenous but unobservable to consumers involves the idea of a "quality-guaranteeing price" (see, e.g., KLEIN AND LEFFLER [1981], and BESTER [1998]).

<sup>4</sup> Most disclosure models do not consider liability cost for the firm; those that do consider it assume perfect compensation, so consumers do not care about quality (see, for example, POLINSKY AND SHAVELL [2006]).

model with a continuum of types that permits marginal cost to be either increasing in safety or decreasing in safety; the signaling portion of our current model is essentially a two-type version of this model. DAUGHETY AND REINGANUM [2005] provide a model with a continuum of types and unit demand; in that paper, the firm can commit to a disclosure policy *before* it learns its type, but cannot make a disclosure after learning its type. In the current paper, we model the disclosure decision as occurring *after* the firm has learned its type, consistent with the usual timing in the disclosure literature.<sup>5</sup> Finally, in DAUGHETY AND REINGANUM [2007a], [2007c], no disclosure is possible but multiple firms engage in price–quality signaling under the assumption that marginal cost is increasing in quality.<sup>6</sup>

On the disclosure side of the literature, JOVANOVIĆ [1982] and POLINSKY AND SHAVELL [2006] are perhaps the closest in certain attributes to our paper. Jovanovic assumes that a firm knows the quality of its own good, but disclosure is costly. Since marginal cost does not vary with quality, all firms that do not disclose set the same price (that is, price cannot serve as a signal of quality following nondisclosure). POLINSKY AND SHAVELL [2006] examine a model in which firms that may face liability for harm can disclose quality information costlessly, but need not acquire it. They examine the usefulness of mandatory disclosure rules in this context, with particular emphasis on how they affect incentives to acquire information in the first place. Absent liability, if acquisition were costless then skeptical beliefs on the part of consumers would induce the firm to acquire information and then disclose it. But if information is costly to acquire, then a firm may not disclose its quality either because it does not know its quality, or because it knows its quality is low (a firm which learns that its product is of high quality will disclose this). Again, since marginal cost does not vary with quality, price cannot serve as a signal of quality following nondisclosure. Polinsky and Shavell then consider liability under both a negligence standard and strict liability. Since the firm will meet the standard of care in a negligence regime, this will reduce to the previous analysis in which the consumer bears all of the loss (and, since liability costs are zero, the firm’s marginal cost does not vary with quality). When the firm faces strict liability, then its marginal liability costs must vary with quality, but in this case Polinsky and Shavell assume that the consumer is fully-compensated and hence she no longer cares about quality (and the firm no longer cares about disclosure).

In our model, the acquisition of information is costless but its disclosure is costly, and thus some firm types will not disclose (as in JOVANOVIĆ [1982]). However, because marginal cost varies with safety (and because consumers still bear some of the loss, so they care about safety), the firm’s price will serve as a signal of its product’s safety following nondisclosure. Thus, our assessment of the value of mandatory disclosure focuses not on the amount of information that is ultimately provided, but on whether it is provided through the socially-optimal

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<sup>5</sup> One exception is LEVIN, PECK, AND YE [2007], who consider both when the disclosure decision is made before, and when it is made after, the firm learns its product quality.

<sup>6</sup> SPENCE [1977] and ARLEN AND BUNTING [2006] ask whether voluntary contracting over liability can signal quality when price is determined competitively.

channel (e.g., disclosure or signaling). In a companion paper (DAUGHETY AND REINGANUM [2007b]), we examine a version of the signaling-versus-disclosure model with a continuum of quality levels; however, that paper does not consider firm liability for losses nor does it consider the effects of naive consumers on pricing and disclosure.

The only published paper of which we are aware that involves both disclosure and signaling is FISHMAN AND HAGERTY [2003].<sup>7, 8</sup> However, in their model disclosure and signaling are not *substitutes* (as they are in our model), but *complements*, due to an externality between different types of consumers. Thus, signaling does not accompany nondisclosure in their model (because they maintain the crucial assumption that marginal cost is the same for high- and low-quality products); it can only accompany disclosure. This occurs because they assume two different types of consumer, each of which demands one unit; one type of consumer becomes “informed” about quality when a disclosure is made, while the other remains “uninformed” about actual quality, but is aware that a disclosure has been made. In this setting, an “uninformed” consumer can draw an inference from the firm’s price about its quality. To see how this can happen, suppose that most consumers are capable of becoming “informed.” Then a firm that makes a disclosure and charges a high price will only do so if it is a high-quality firm, for if it were a low-quality firm charging a high price, it would alienate all of the informed consumers. So an uninformed consumer who knows that a disclosure was made (but not its content) can infer from a high price that the firm has a high-quality product. Our model is very different from that of FISHMAN AND HAGERTY [2003] in that all consumers become informed about safety when the firm discloses it; moreover, our consumers have downward-sloping demand. Our firm has a marginal cost that is safety-dependent, though it may be increasing or decreasing in safety. Thus, if a firm does not disclose its safety directly, it reveals it through its price: disclosure and signaling are substitutes.

## 1.2 Plan of the Paper

In section 2, we describe the model set-up and notation. Section 3 characterizes equilibrium pricing with and without disclosure. Section 4 compares equilibrium disclosure with socially-optimal disclosure and considers the desirability of mandatory disclosure rules. Section 5 modifies the preceding analysis to incorporate naive consumers who do not apply the skeptical beliefs that are integral to both signaling and disclosure models. While these consumers become informed when safety is disclosed, they do not update their beliefs about safety based on the product’s price (following nondisclosure). Section 6 summarizes and

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<sup>7</sup> Since completing this paper, we have become aware of a working paper by CALDIERARO, SHIN AND STIVERS [2007]; there only some consumers observe disclosure, leading to both disclosure and signaling by the firms. Even though disclosure is free, consumers cannot induce “unraveling” as they cannot employ skeptical beliefs.

<sup>8</sup> A related paper from the auction literature is CAI, RILEY, AND YE [2007], where the seller’s reserve price signals her value to the buyers. In the working paper version, the authors briefly discuss an application involving costly external value certification.

suggests some possible extensions. Extensive derivations and proofs are provided in the Technical Appendix.<sup>9</sup>

## 2 Model Set-Up

### 2.1 Safety

Assume that a single firm produces a product that may be of either high ( $H$ ) safety or low ( $L$ ) safety; let  $\lambda \in (0, 1)$  denote the probability that the product is of high safety. Safety itself takes the form of a probability that the consumer is not harmed by the product. Let  $\theta_i$  represent the probability that the consumer is not harmed by the product of type  $i \in \{H, L\}$ , where  $1 > \theta_H > \theta_L > 0$ . Thus, either type of product may be used without harm in a given instance of its consumption, but either type of product may also cause harm in a given instance; the key attribute is that higher-safety products are more likely to be used without harm.

### 2.2 Liability

When use of the product causes harm, a loss is created; this loss includes the actual harm experienced by the consumer, plus any costs associated with settlement or trial. The liability system allocates the loss between the consumer and the firm by specifying how much compensation is due to the consumer from the firm, and under what circumstances. When a consumer is physically (or emotionally) harmed, the liability system supersedes any contractual liability such as a warranty (which might otherwise serve as a signal of safety). Most warranties offer very limited compensation, such as repair or replacement of the item. Moreover (allowing for litigation costs and the difficulty of proving causation), the extent of contractual liability that must be assumed in order to signal safety would typically exceed the expected harm, and thus might run afoul of the penalty doctrine.<sup>10</sup> To illustrate how the liability system allocates the loss, we note that (assuming strict liability) the firm is responsible for the consumer's harm, but each party is responsible for her own legal costs. Moreover, it may be difficult for the plaintiff to establish causation in a given instance. Thus, we expect that consumers will bear some residual loss, and we denote the anticipated uncompensated loss to the consumer by  $\delta > 0$ . We denote the firm's anticipated liability payment in the event of harm by  $\gamma > 0$ ; thus, the total loss is given by  $T = \delta + \gamma$ .

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<sup>9</sup> <http://www.vanderbilt.edu/econ/faculty/Daughety/JITETechnicalAppendix.pdf>.

<sup>10</sup> Under the penalty doctrine, stipulated damages in excess of expected damages are not enforced (REA JR. [1998, p. 24]).

### 2.3 Consumers

Both types of product provide utility to the consumer, but a unit that fails provides less utility. In particular, assume that the consumer's utility is quadratic in the quantity consumed of the product of interest, with the coefficient on the quadratic term denoted  $\beta$ , and the coefficient on the linear term denoted  $\alpha$  in the case of a unit that does not cause harm and  $\alpha - \delta$  in the case of a unit that fails, causing the consumer to bear the loss  $\delta$ . The consumer may or may not be able to observe directly the product's safety before purchase. Let the *perceived safety* of the good be denoted  $\tilde{\theta}$ . If the product's safety is observable before purchase (e.g., because the firm discloses it), then  $\tilde{\theta} = \theta_i$ , for  $i \in \{H, L\}$ ; on the other hand, if the product's safety is not observable before purchase, then these perceptions will be determined as part of a perfect Bayesian equilibrium.

The consumer's utility function is quasi-linear in all other goods; thus, if the price of the product is  $p$ , the consumer's income is  $I$ , and she consumes  $q$  units of the good with perceived safety  $\tilde{\theta}$ , then her utility is given by:

$$U(p, q, \tilde{\theta}) \equiv [\alpha - (1 - \tilde{\theta})\delta]q - \beta(q)^2/2 + I - pq.$$

Therefore, the consumer's demand for the product of perceived quality  $\tilde{\theta}$  is given by:

$$q(p, \tilde{\theta}) = [\alpha - (1 - \tilde{\theta})\delta - p]/\beta.$$

Note that the quantity demanded is an increasing function of perceived quality.

### 2.4 The Firm

The firm of type  $i$  manufactures units of the product at a constant marginal cost of  $c(\theta_i)$ ,  $i \in \{H, L\}$ . This cost consists of marginal manufacturing cost, denoted  $k\theta_i$  with  $k > 0$ , which is increasing in safety (that is, safer products cost more to produce) and marginal expected liability cost, denoted  $\gamma(1 - \theta_i)$ , which is decreasing in safety (that is, safer products generate lower expected liability cost). Thus,  $c(\theta_i) = k\theta_i + \gamma(1 - \theta_i)$  is the firm's full marginal cost; the firm's full marginal cost is increasing in safety if  $k > \gamma$ , and decreasing in safety if  $k < \gamma$ . If the firm does not bear substantial liability for a consumer's harm, then  $\gamma$  will be small and thus  $k > \gamma$ . On the other hand, if the firm does bear substantial liability for a consumer's harm, then  $\gamma$  will be large and thus  $k < \gamma$ .<sup>11</sup>

The gross profits for the firm depend on its true price–cost margin and consumer demand, which depends on perceived safety:

$$\pi(p, \theta_i, \tilde{\theta}) \equiv (p - c(\theta_i)) [q(p, \tilde{\theta})].$$

The firm of type  $i$  can affect its perceived safety in two ways, through its disclosure policy and its price. If the firm elects to disclose its safety, then  $\tilde{\theta} = \theta_i$ .

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<sup>11</sup> We rule out the knife-edge case of  $k = \gamma$ , since this implies that marginal cost is the same for both levels of safety. In this case, price cannot serve as a signal of safety and we are back in the traditional disclosure model.

We assume that disclosure requires a cost of  $D > 0$ ; this reflects the need for verification of the firm's type by some independent third party. This verification could be achieved by testing a sample of units, or by surveying a sample of consumers about their experiences (without providing them any reward that is contingent on their answers). If the firm elects not to disclose its safety, consumers will base their perceptions of safety on the accompanying price. We model the choice of disclosure policy and price as being simultaneous, once the firm has learned its true type.

Finally, let  $c_i \equiv c(\theta_i)$  and  $\alpha_i \equiv \alpha - (1 - \theta_i)\delta$ . Then  $\alpha_H - \alpha_L = \delta(\theta_H - \theta_L) > 0$ , and  $c_H - c_L = (k - \gamma)(\theta_H - \theta_L) (> = <) 0$  as  $k (> = <) \gamma$ . The following parameter restrictions will be maintained throughout the paper.

ASSUMPTION 1  $\alpha_H - c_H > \alpha_L - c_L$ .

ASSUMPTION 2  $\alpha_L > \max \{c_H, c_L\}$ .

Assumption 1 implies that the high-safety product is socially-preferred to the low-safety product (even though the high-safety product is more costly to produce). Alternatively put, Assumption 1 implies that the combined loss from an accident ( $\delta + \gamma$ ) exceeds the incremental production cost of improving safety ( $k$ ). Assumption 2 ensures that both firm types can make positive profits, whether they are correctly-perceived or mis-perceived as the other type (since  $\alpha_H > \alpha_L$ , it follows from Assumption 2 that  $\alpha_H > \max \{c_H, c_L\}$  as well). Another implication of Assumption 2 is that both products are socially-beneficial; consumers might, in principle, over-pay for a unit, but neither product type generates negative expected surplus.

### 3 Equilibrium Pricing with and without Disclosure

In this section, we first characterize the equilibrium pricing behavior that accompanies a decision to disclose safety directly. Next, we characterize equilibrium pricing behavior when the disclosure cost  $D$  is prohibitively high; this involves solving a relatively straightforward signaling model in which price reveals safety. In section 4, we lower the disclosure cost to determine which types, if any, will defect from signaling to the outside option of direct disclosure.

Note that any firm type that discloses can (and will) charge its full-information monopoly price (that is, the price it would charge if consumers could observe safety directly). Let  $P_i^f$  denote the full-information monopoly price for a firm producing a product of type  $i$ , and let  $\Pi_i^f$  denote the corresponding full-information monopoly profits. Then  $P_i^f = (\alpha_i + c_i)/2$  and  $\Pi_i^f = (\alpha_i - c_i)^2/4\beta$ . Now let  $P_i^d$  denote the equilibrium price that accompanies disclosure for a firm producing a product of type  $i$ , and let  $\Pi_i^d$  denote the corresponding equilibrium profits. Since disclosure is costly, but the pricing game accompanying disclosure

is one of full information, the equilibrium price and payoff for a disclosing firm of type  $i$  are simply  $P_i^d = P_i^f$  and  $\Pi_i^d = \Pi_i^f - D$ ,  $i \in \{H, L\}$ .

Now suppose that the disclosure cost  $D$  is prohibitively high, so it is common knowledge that no firm type will choose disclosure. Then consumers will try to infer product safety from the price that is being charged. We will characterize a (refined) separating perfect Bayesian equilibrium in which price serves as a signal of safety.<sup>12</sup> Let  $B(p)$  be the belief function that relates the firm's price to the consumer's perceived safety; thus, if the firm charges the price  $p$ , then it is inferred to have safety  $B(p) \in \{\theta_H, \theta_L\}$ . A firm charging price  $p$ , with true safety  $\theta_i$  and perceived safety  $\tilde{\theta} = B(p)$ , obtains profit of  $\pi(p, \theta_i, B(p)) \equiv (p - c(\theta_i))[\alpha - (1 - B(p))\delta - p]/\beta$ . In addition to incentive compatibility constraints that ensure separation, a separating perfect Bayesian equilibrium requires that consumers infer correctly the firm's type from its price; that is, the beliefs must be consistent with equilibrium play. Let  $P_H^s$  and  $P_L^s$  denote the equilibrium prices for a high-safety type and a low-safety type, respectively, in a separating perfect Bayesian equilibrium and let  $\Pi_H^s$  and  $\Pi_L^s$  denote the corresponding equilibrium profits.

**DEFINITION 1** *Suppose that  $D$  is prohibitively high, so neither firm type discloses. A separating perfect Bayesian equilibrium in prices consists of a pair of prices  $(P_H^s, P_L^s)$ , with  $P_H^s \neq P_L^s$ , and beliefs  $B^*(p)$  such that:*

- (i)  $\pi(P_H^s, \theta_H, \theta_H) \geq \max_p \pi(p, \theta_H, B^*(p));$
- (ii)  $\pi(P_L^s, \theta_L, \theta_L) \geq \max_p \pi(p, \theta_L, B^*(p));$
- (iii)  $B^*(P_H^s) = \theta_H, B^*(P_L^s) = \theta_L.$

The following proposition is proved in the Technical Appendix.

**PROPOSITION 1** *There is a unique (refined) separating perfect Bayesian equilibrium in prices:*

- (i) *the low-safety type always charges its full-information price,  $P_L^s = (\alpha_L + c_L)/2$ ;*
- (ii) *when  $c_H > c_L$ , then  $P_H^s = 0.5(\alpha_H + c_L + \{(\alpha_H - c_L)^2 - (\alpha_L - c_L)^2\}^{1/2}) > P_H^f$ ; the beliefs supporting this equilibrium are  $B^*(p) = \theta_L$  when  $p < P_H^s$  and  $B^*(p) = \theta_H$  when  $p \geq P_H^s$ ;*
- (iii) *when  $c_L > c_H$ , then  $P_H^s = \min \{0.5(\alpha_H + c_L - \{(\alpha_H - c_L)^2 - (\alpha_L - c_L)^2\}^{1/2}), P_H^f\} \leq P_H^f$ ; the supporting beliefs are  $B^*(p) = \theta_L$  when  $p > P_H^s$  and  $B^*(p) = \theta_H$  when  $p \leq P_H^s$ .*

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<sup>12</sup> Although there exists a continuum of separating equilibria, the Intuitive Criterion (CHO AND KREPS [1987]) selects a unique one; see the Technical Appendix for details. Similarly, although pooling equilibria exist, they do not survive refinement using the Intuitive Criterion (see the Technical Appendix).

It is worth noting that, even when the high-safety type's price is distorted, it still belongs to the interval  $(c_H, \alpha_H)$ , so both the price–cost margin and equilibrium output are positive.

The intuition for the structure of this equilibrium is as follows. First, since the low-safety type will be revealed in a separating equilibrium, it can do no better than to price at its full-information price and obtain its full-information profits. Second, in order to ensure separation, the high-safety type must choose a price that a low-safety type would not mimic. When the firm does not bear substantial liability for a consumer's harm, then  $\gamma$  is small and  $k - \gamma > 0$ , implying that  $c_H - c_L > 0$ . Thus, the proposition says that when the firm does not bear substantial liability for a consumer's harm, then the high-safety type signals its safety by distorting its price *upward* from its full-information price. Increasing its price (and thus foregoing some sales) is less expensive for the high-safety type than it is for the low-safety type, because the low-safety type has the larger price–cost margin for any given price and hence loses more than the high-safety type on each foregone sale. There is a high enough price  $P_H^s$  (and thus a low enough sales volume) that makes the low-safety type indifferent between mimicry and accepting its full-information profits.

On the other hand, when the firm bears substantial liability for a consumer's harm, then  $\gamma$  is large and  $\gamma - k > 0$ , implying that  $c_L - c_H > 0$ . We will refer to the cost difference  $c_L - c_H$ , which measures the low-safety product's cost disadvantage, as “moderate” when  $(c_L - c_H)^2 < (\alpha_H - \alpha_L)(\alpha_H + \alpha_L - 2c_L)$ , and as “large” when  $(c_L - c_H)^2 \geq (\alpha_H - \alpha_L)(\alpha_H + \alpha_L - 2c_L)$ . The proposition indicates that when the cost difference  $c_L - c_H$  is moderate,<sup>13</sup> then the high-safety type must distort its price *downward* from its full-information value. Possible examples of downward-distorted pricing to signal high quality are free samples of pharmaceuticals or low prices for high-quality fast food items (such as McDonald's).<sup>14</sup>

Downward distortion can deter mimicry because a price decrease (which increases sales) is less attractive for a low-safety type than for a high-safety type since the low-safety type now has a *lower* price–cost margin for any given price. There is a low enough price  $P_H^s$  that makes the low-safety type indifferent between mimicry and accepting its full-information profits. When the cost difference  $c_L - c_H$  is large, then the high-safety type need not distort its price in order to be recognized; its full-information price is already so low that the low-safety type does not want to mimic it, even if doing so would result in an inference of high safety.

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<sup>13</sup> A sufficient condition for this cost disadvantage to be moderate is that the high-safety type's full-information price is higher than that of the low-safety type: that is,  $P_H^f = (\alpha_H + c_H)/2 > (\alpha_L + c_L)/2 = P_L^f$  or, equivalently,  $\gamma - k < \delta$ .

<sup>14</sup> We thank Ben Hermalin for this latter example.

#### 4 Equilibrium and Socially-Optimal Disclosure

An immediate implication of Proposition 1 is that the high-safety type suffers a loss in profit due to private information: that is,  $\Pi_H^f - \Pi_H^s$  is positive (unless the low-safety product's cost disadvantage is large, in which case  $\Pi_H^f - \Pi_H^s = 0$ ), while the low-safety type suffers no loss: that is,  $\Pi_L^f - \Pi_L^s = 0$ . Thus, as the disclosure cost  $D$  is lowered from its prohibitively high level, it is the high-safety type that will defect from the signaling equilibrium to the outside option of direct disclosure: a high-safety type will choose to disclose when  $D \leq \Pi_H^f - \Pi_H^s$ . Since the low-safety type's payoff will continue to be the same regardless of the high-safety type's decision to disclose (the low-safety type will continue to choose its full-information monopoly price), the low-safety type continues to eschew disclosure. Only at  $D = 0$  does the low-safety type become indifferent between disclosing and not disclosing (and similarly for the high-safety type when the low-safety product's cost disadvantage is large). These results are summarized in the following proposition.

**PROPOSITION 2**

- (i) A low-safety type will not disclose for any  $D > 0$ .
- (ii) When  $c_H > c_L$ , or when  $c_L > c_H$  but this cost difference is moderate, there is a range of disclosure costs  $D \in (0, \Pi_H^f - \Pi_H^s)$ , for which the high-safety type will disclose;
- (iii) When  $c_L > c_H$  and this cost difference is large, then a high-safety type will not disclose for any  $D > 0$ .

In this paper we consider only a regime of strict liability. It is worth noting, however, that these results are essentially robust to an alternative liability regime in which disclosure relieves the firm of liability.<sup>15</sup> This is because the full-information profits are unchanged by this liability shift, as long as the total anticipated loss ( $\gamma + \delta$ ) is constant. If the loss  $\gamma$  is shifted to the consumer upon the firm's disclosure of its type  $\theta$ , the consumer simply subtracts  $\gamma(1 - \theta)$  from her maximum willingness-to-pay for the good. The firm's profit margin, the consumer's equilibrium demand, and thus the firm's profit, are all unchanged. This invariance to the allocation of losses under full information can also be seen by inspection of the firm's full-information profit function, which depends only on the total expected harm and not on how it is divided between the parties. Thus, this shift also leaves unchanged the firm's incentive to disclose. To the extent that a shift to no liability following disclosure reduces the total anticipated loss (since expected litigation costs will now be zero), the firm's profits following disclosure will be somewhat higher and thus the incentives for disclosure will be somewhat stronger. In particular, if the disclosure cost is sufficiently small, even an  $L$ -type

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<sup>15</sup> See SPIER [2006] for a model in which a firm's post-sale disclosure allows consumers to fine-tune their precaution decisions. She provides conditions under which a policy that exempts a disclosing firm from liability improves welfare.

firm may find it optimal to disclose if this would insulate it from liability for harm.

#### 4.1 Welfare Analysis of Voluntary Disclosure

As was mentioned in the Introduction, when marginal cost varies with safety the alternative to disclosure is *not* “nondisclosure,” but signaling: both firms’ types are ultimately revealed, but possibly through different channels. A welfare analysis of disclosure then rests not on the amount of information that is ultimately provided, but on whether it is provided through the socially-optimal channel. The firm pays a lump-sum cost associated with disclosure, while the firm’s cost of signaling sometimes involves distortions in pricing and output. Although the lump-sum cost of disclosure affects total surplus in the same way as it affects profits (that is, via simple subtraction), distortions in pricing and output can affect firm profits and consumer or total surplus in very different ways.

In a regime of voluntary disclosure, the low-safety type does not engage in costly disclosure, because signaling entails no cost. Thus, the private and social incentives to disclose coincide for the low-safety type. A comparison of the high-safety type’s incentives to disclose with the social incentives requires a comparison of output levels; let  $Q_H^s$ ,  $Q_H^f$ , and  $Q_H^o$  denote the output of the high-safety type in the signaling equilibrium, under full information, and at the social optimum, respectively.<sup>16</sup> Since the signaling price  $P_H^s \in (c_H, \alpha_H)$ , it is straightforward to show that if  $c_H > c_L$  (that is, if the firm does not bear substantial liability for a consumer’s harm) then  $Q_H^s < Q_H^f < Q_H^o$ . Thus, both profits *and* consumer surplus<sup>17</sup> (and hence total surplus,<sup>18</sup> denoted  $S_i^t$ , where  $i \in \{H, L\}$  and  $t = s, f, \text{ or } o$  as appropriate) will be higher under full information than under signaling, since full information results in greater output (though it is still less than the socially-optimal amount). Since the firm incorporates only the effect on profits in making its disclosure decision, there will exist values of the disclosure cost  $D$  for which the firm will choose not to disclose when it would be socially optimal for it to do so (i.e.,  $\Pi_H^f - \Pi_H^s < D < S_H^f - S_H^s$ ).

If  $c_L - c_H > 0$  (that is, if the firm bears substantial liability for a consumer’s harm) and the low-safety product’s cost disadvantage  $c_L - c_H$  is large, then  $Q_H^s = Q_H^f < Q_H^o$ . In this case, the private and social incentives for disclosure again coincide, since the high-safety type will not disclose for any  $D > 0$ , and this is socially optimal (because, in this case, the high-safety type need not distort its price and output to reveal safety). However, if  $c_L - c_H > 0$  and the low-safety

<sup>16</sup> These outputs are  $Q_i^s = [\alpha - (1 - \theta)\delta - P_i^s] / \beta$ ;  $Q_i^f = [\alpha - (1 - \theta)\delta - P_i^f] / \beta$ ; and  $Q_i^o = [\alpha - (1 - \theta)\delta - c(\theta)] / \beta$ , for  $i \in \{H, L\}$ .

<sup>17</sup> Consumer surplus is  $CS_i^s = [\alpha - (1 - \theta)\delta - P_i^s]^2 / 2\beta$ ;  $CS_i^f = [\alpha - (1 - \theta)\delta - P_i^f]^2 / 2\beta$ ; and  $CS_i^o = [\alpha - (1 - \theta)\delta - c(\theta)]^2 / 2\beta$ , for  $i \in \{H, L\}$ .

<sup>18</sup> Total surplus is  $S_i^s = CS_i^s + \Pi_i^s$ ;  $S_i^f = CS_i^f + \Pi_i^f$ ; and  $S_i^o = CS_i^o + \Pi_i^o$ , for  $i \in \{H, L\}$ .

product's cost disadvantage  $c_L - c_H$  is moderate, then it is straightforward to show that  $Q_H^f < Q_H^s < Q_H^o$ . In this case, signaling requires the firm to lower its price and expand its output relative to the full-information monopoly level, which provides a benefit to consumers and an increase in total surplus. Thus, when  $c_L - c_H > 0$  consumers (and a social planner) would always prefer information transmission to occur through signaling rather than disclosure. Clearly there are values of the disclosure cost  $D > 0$  for which the firm also prefers signaling to disclosure, but there are also values of  $D > 0$  for which the firm can improve its profits by disclosing (since it can then raise its price and reduce its output to coincide with the full-information monopoly optimum). This disclosure is socially excessive, even if it is free.

#### 4.2 Mandatory Disclosure

The foregoing indicates that there may be too little disclosure when the firm does not bear substantial liability for a consumer's harm (i.e., when  $c_H > c_L$ ), while there may be too much disclosure when the firm does bear substantial liability for a consumer's harm (i.e., when  $c_L > c_H$ , but this difference is moderate). Thus, the only parametric regime in which mandatory disclosure could play a positive role is when  $c_H > c_L$  and  $D \in (\Pi_H^f - \Pi_H^s, S_H^f - S_H^s)$ . Since a mandatory disclosure rule yields benefits only when product safety is high but imposes the disclosure cost in either state, the expected social benefits of such a rule are  $\lambda(S_H^f - S_H^s) - D$ ; assuming that the firm bears the cost  $D$ , any benefits of mandatory disclosure accrue to consumers (because, by hypothesis,  $D > \Pi_H^f - \Pi_H^s$ ). This suggests that mandatory disclosure requirements are most likely to be beneficial in markets wherein safety is likely to be high (i.e.,  $\lambda$  is high), safer units are more costly to manufacture, the firm does not bear substantial liability for a consumer's harm (i.e.,  $c_H > c_L$ ), and the disclosure cost is neither too high nor too low (i.e.,  $D \in (\Pi_H^f - \Pi_H^s, S_H^f - S_H^s)$ ).

Although we have assumed thus far that product safety is exogenous, one could append a prior stage to this model wherein a firm could invest so as to affect the distribution from which its safety is ultimately drawn (safety-related investment would affect  $\lambda$ ); for an example of this, see DAUGHETY AND REINGANUM [1995]. This reveals a further benefit of mandatory disclosure, which arises under roughly the same circumstances as above: that is, when  $c_H > c_L$  and the disclosure cost is sufficiently high (specifically, when  $D > \Pi_H^f - \Pi_L^s$ ). Under these parametric conditions, the high-safety type (by choosing optimally between disclosure and signaling) earns  $\max \{ \Pi_H^s, \Pi_H^f - D \}$ . It is straightforward to show (see the Technical Appendix) that  $\Pi_H^s < \Pi_L^s$  when  $c_H > c_L$ ; moreover,  $\Pi_H^f - D < \Pi_L^f$  by hypothesis. Thus, a firm that anticipates these high-safety profits has little incentive to try to improve its product quality; indeed, it will invest to try to lower its likelihood of ultimately producing a safer product. This perverse result is typical of price-quality signaling models; it can be reversed in a variety of sensible ways when one wishes to make safety endogenous. For example, the risk

$\theta$  could reflect a technology with alternative uses (e.g., a “better” technology improves safety when used to produce therapeutic drugs, and yields higher output when used to produce generic multi-vitamins). While high quality is disadvantageous in the market for the product with the safety attribute, it can still be advantageous for the firm overall (DAUGHETY AND REINGANUM [2005]). Alternatively, the model we are exploring might concern a new product whose safety is initially uncertain but will eventually become common knowledge (BAGWELL AND RIORDAN [1991]). While high safety is disadvantageous in the introductory period, it is advantageous in the long run.

However, under a mandatory disclosure rule, the high-safety type would earn higher profits than the low-safety type, since  $\Pi_H^f - D - (\Pi_L^f - D) = \Pi_H^f - \Pi_L^f > 0$ . Now the firm has an incentive to invest so as to improve its likelihood of ultimately producing a safer product. Since safer products are socially-preferred, this effect of a mandatory disclosure rule is an additional benefit.<sup>19</sup> Thus, a mandatory disclosure rule that appears “wasteful” *ex post* may be optimal *ex ante* when the incentives for safety-enhancing R&D are included.

When  $c_H < c_L$ , then any disclosure is welfare-impairing (relative to price-signaling). While it may be socially optimal to ban disclosure, this does not seem either feasible or sensible. However, if one were to ban disclosure, then both firms would earn their signaling profits, and it is straightforward to show (see the Technical Appendix) that  $\Pi_H^s > \Pi_L^s$  when  $c_H < c_L$ . Moreover, without such a rule the high-safety type would choose optimally between disclosure and signaling, earning  $\max \{ \Pi_H^s, \Pi_H^f - D \} > \Pi_L^s$ . Thus, when  $c_H < c_L$  a firm has an incentive to engage in safety-enhancing R&D regardless of whether disclosure is mandatory, voluntary, or prohibited.

## 5 The Effect of Naive Consumers

This section will incorporate a small fraction, denoted  $\varepsilon$  of consumers who are “naive” in the sense that they do not apply the skeptical beliefs that are integral to both signaling and disclosure models. In what follows, we will indicate with a “ $\wedge$ ” those expressions that change due to the inclusion of naive consumers. Wherever the expression in question remains unchanged, we will omit the “ $\wedge$ ” to emphasize that it is unchanged. We first examine the case of naively optimistic consumers and then we consider the alternative case of naively pessimistic consumers. Finally, we provide a summary of the results for both types of *naiveté*, emphasizing those results that are robust and those that differ.

### 5.1 Naively Optimistic Consumers

We assume that naively optimistic consumers become informed when the firm elects to disclose its safety, and thus the full-information prices and profits remain as before:  $P_i^f = (\alpha_i + c_i)/2$  and  $\Pi_i^f = (\alpha_i - c_i)^2/4\beta$ ,  $i \in \{H, L\}$ , where  $\alpha_H \equiv \alpha -$

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<sup>19</sup> We thank Abraham Wickelgren for identifying this additional benefit.

$(1 - \theta_H)\delta$  and  $\alpha_L \equiv \alpha - (1 - \theta_L)\delta$ . However, these consumers do not update their beliefs about safety based on the price charged following nondisclosure. Instead, they naively believe that the product is of high safety and purchase according to the demand curve  $q^{\text{NO}}(p) \equiv [\alpha - (1 - \theta_H)\delta - p]/\beta$ , where “NO” stands for “naively optimistic.” The remaining fraction of consumers continue to exercise skeptical beliefs and purchase according to the demand function  $q(p) = [\alpha - (1 - B(p))\delta - p]/\beta$ .

The firm, accounting for these different consumer populations, faces the demand curve  $\hat{q}(p) \equiv \varepsilon q^{\text{NO}}(p) + (1 - \varepsilon)q(p) = [\alpha - \varepsilon(1 - \theta_H)\delta - (1 - \varepsilon)(1 - B(p))\delta - p]/\beta$ . This demand curve is similar to the original one except that the expression  $\alpha - (1 - B(p))\delta$  is replaced by  $\alpha - \varepsilon(1 - \theta_H)\delta - (1 - \varepsilon)(1 - B(p))\delta$ . These two expressions are the same when skeptical consumers infer that the product is of high safety; that is,  $\alpha_H = \alpha - \varepsilon(1 - \theta_H)\delta - (1 - \varepsilon)(1 - \theta_H)\delta = \alpha - (1 - \theta_H)\delta$ . However, when skeptical consumers infer that the product is of low safety, naively optimistic consumers continue to believe it is of high safety. Then there is a modified version of  $\alpha_L$ , denoted  $\hat{\alpha}_L$ , where  $\hat{\alpha}_L \equiv \alpha - \varepsilon(1 - \theta_H)\delta - (1 - \varepsilon)(1 - \theta_L)\delta > \alpha_L$ .

We continue to maintain Assumptions 1 and 2 (substituting  $\hat{\alpha}_L$  for  $\alpha_L$ ), which means that all of the previous analysis continues to apply with the appropriate substitution of  $\hat{\alpha}_L$  for  $\alpha_L$ . Thus, the separating equilibrium prices and profit for the low-safety type now become:  $\hat{P}_L^s = (\hat{\alpha}_L + c_L)/2$  and  $\hat{\Pi}_L^s = (\hat{\alpha}_L - c_L)^2/4\beta$ . Notice that the low-safety type no longer obtains its true full-information profits (as it would do under disclosure); rather, it obtains the profits it would obtain if skeptical consumers knew it was of low safety, while naively optimistic consumers continue to believe that it is of high safety. The separating equilibrium price for the high-safety type is likewise obtained by substituting  $\hat{\alpha}_L$  for  $\alpha_L$ . This yields the following modified version of Proposition 1.

**PROPOSITION 3** *Assuming a small fraction of naively optimistic consumers, there is a unique (refined) separating perfect Bayesian equilibrium in prices:*

- (i) *the low-safety type charges  $\hat{P}_L^s = (\hat{\alpha}_L + c_L)/2$ ;*
- (ii) *when  $c_H > c_L$ , then  $\hat{P}_H^s = 0.5(\alpha_H + c_L + \{(\alpha_H - c_L)^2 - (\hat{\alpha}_L - c_L)^2\}^{1/2}) > P_H^f$ ; the beliefs supporting this equilibrium are  $B^*(p) = \theta_L$  when  $p < \hat{P}_H^s$  and  $B^*(p) = \theta_H$  when  $p \geq \hat{P}_H^s$ ;*
- (iii) *when  $c_L > c_H$ , then  $\hat{P}_H^s = \min \{0.5(\alpha_H + c_L - \{(\alpha_H - c_L)^2 - (\hat{\alpha}_L - c_L)^2\}^{1/2}), P_H^f\} \leq P_H^f$ ; the supporting beliefs are  $B^*(p) = \theta_L$  when  $p > \hat{P}_H^s$  and  $B^*(p) = \theta_H$  when  $p \leq \hat{P}_H^s$ .*

First we consider the impact of a small fraction of naively optimistic consumers on the separating equilibrium when  $c_H > c_L$ . Since both  $\hat{P}_L^s$  and  $\hat{\Pi}_L^s$  are increasing functions of  $\hat{\alpha}_L$ , it follows that the addition of naively optimistic consumers raises

both the equilibrium price and profits for the low-safety type; that is,  $\hat{P}_L^s > P_L^s$  and  $\hat{\Pi}_L^s > \Pi_L^s$ . Thus a firm producing a low-safety product benefits from the existence of naively optimistic consumers who persistently believe that its product is of higher safety than it really is. What may be less expected is that a firm producing a high-safety product also benefits from the existence of such naively optimistic consumers; that is,  $\hat{\Pi}_H^s > \Pi_H^s$ . To see this, first note that both consumer populations are using the correct safety assessment, and hence both purchase according to the demand function  $q(p) \equiv [\alpha - (1 - \theta_H)\delta - p]/\beta$ ; the full-information price  $P_H^f$  maximizes profits given this demand function. Second, recall that the safer firm type distorts its price upward (from its full-information price) to signal safety when  $c_H > c_L$ . While there is still some upward distortion, since  $\hat{P}_H^s$  is a decreasing function of  $\hat{\alpha}_L$ , it follows that  $\hat{P}_H^s < P_H^s$ . That is, there is less upward distortion, and hence the high-safety type's price provides higher profits (i.e.,  $\hat{\Pi}_H^s > \Pi_H^s$ ) when there are some naively optimistic consumers.

The intuition for this result is as follows. Naively optimistic consumers buy from a low-safety type as if it were a high-safety type, which increases the low-safety type's profits in a separating equilibrium. Consequently, there is a reduced temptation for the low-safety type to mimic the high-safety type's price (its sales volume would still go up if it were inferred to be of high safety, but now only among skeptical consumers). Since the high-safety type's price is set so as to just deter mimicry by the low-safety type, the high-safety type can lower its price toward its full-information optimum, which improves its profits. In addition to this externality between the two types of firm, there is an externality between the two consumer populations. In particular, the naively optimistic consumers raise the price in state  $L$  (since they purchase as if the product were of high safety, driving up the price) and lower the price in state  $H$  (since the high-safety type need not distort its price upward as much to signal high safety).

Next we consider the impact of a small fraction of naively optimistic consumers on the separating equilibrium when  $c_L > c_H$ . The impact of naively optimistic consumers on the low-safety type is the same: both prices and profits are higher. Moreover, the high-safety firm continues to benefit from the presence of naively optimistic consumers, though the effect on its price is reversed. Both consumer populations are using the correct safety assessment, and hence both purchase according to the demand function  $q(p) \equiv [\alpha - (1 - \theta_H)\delta - p]/\beta$ , but the safer firm type distorts its price downward from its full-information price to signal safety when  $c_L > c_H$ .<sup>20</sup> While there is still some downward distortion, since  $\hat{P}_H^s$  is now an increasing function of  $\hat{\alpha}_L$ , it follows that  $\hat{P}_H^s > P_H^s$ . That is, there is less downward distortion, and hence the high-safety type's price provides higher profits (since it is closer to the full-information optimum) when there are some naively optimistic consumers. The intuition for why the high-safety type benefits

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<sup>20</sup> Distortion occurs when the high-safety type's cost disadvantage is moderate; when it is large, then naively optimistic consumers have no effect on the high-safety type's price or profits in a separating equilibrium.

is precisely the same as when  $c_H > c_L$ . The low-safety type's higher equilibrium profits imply a reduced temptation for the low-safety type to mimic the high-safety type. Since the high-safety type's price is set so as to just deter mimicry by the low-safety type, the high-safety type can raise its price toward its full-information optimum, which improves its profits. Naively optimistic consumers now cause higher prices in both states of the world.

Finally, the effect of naively optimistic consumers on incentives for disclosure is adverse regardless of the ordering of costs. A firm producing a low-safety product would not disclose even if the cost of disclosure were zero (it prefers to milk the naive consumers), since  $\hat{\Pi}_L^s > \Pi_L^s = \Pi_L^f$ . The high-safety type's incentive to disclose is also reduced; since  $\hat{\Pi}_H^s > \Pi_H^s$ , it follows that  $\Pi_H^f - \hat{\Pi}_H^s < \Pi_H^f - \Pi_H^s$ . Thus, one might ask whether a firm's response to consumer *naiveté* might be to engage in more disclosure. We find that if *naiveté* is interpreted as a persistent belief in high quality, then the answer is "No." Neither type of firm benefits from disabusing consumers of this form of *naiveté*.

## 5.2 Naively Pessimistic Consumers

Now consider what happens if instead of naively optimistic consumers, we incorporate naively pessimistic consumers. As before, these consumers do not update their beliefs about safety based on the price charged following nondisclosure. Instead, they naively believe that the product is of low safety and purchase according to the demand curve  $q^{\text{NP}}(p) \equiv [\alpha - (1 - \theta_L)\delta - p]/\beta$ , where "NP" stands for "naively pessimistic." As before, the remaining fraction of consumers continues to exercise skeptical beliefs and purchases according to the demand function  $q(p) = [\alpha - (1 - B(p))\delta - p]/\beta$ . Thus, the firm now faces the demand curve  $\hat{q}(p) \equiv \varepsilon q^{\text{NP}}(p) + (1 - \varepsilon)q(p) = [\alpha - \varepsilon(1 - \theta_L)\delta - (1 - \varepsilon)(1 - B(p))\delta - p]/\beta$ . This demand curve is similar to the original one except that the expression  $\alpha - (1 - B(p))\delta$  is replaced by  $\alpha - \varepsilon(1 - \theta_L)\delta - (1 - \varepsilon)(1 - B(p))\delta$ . These two expressions are the same when skeptical consumers infer that the product is of low safety; that is,  $\alpha_L = \alpha - \varepsilon(1 - \theta_L)\delta - (1 - \varepsilon)(1 - \theta_L)\delta = \alpha - (1 - \theta_L)\delta$ . However, when skeptical consumers infer that the product is of high safety, naively pessimistic consumers continue to believe it is of low safety. Then there is a modified version of  $\alpha_H$ , denoted  $\hat{\alpha}_H$ , where  $\hat{\alpha}_H \equiv \alpha - \varepsilon(1 - \theta_L)\delta - (1 - \varepsilon)(1 - \theta_H)\delta < \alpha_H$ .

We continue to maintain Assumptions 1 and 2 (substituting  $\hat{\alpha}_H$  for  $\alpha_H$ ), which means that all of the previous analysis continues to apply with the appropriate substitution of  $\hat{\alpha}_H$  for  $\alpha_H$ . As should now be obvious, a modified version of Proposition 3 can be obtained for the naively pessimistic case by making two switches in Proposition 3: (1) replace  $\hat{\alpha}_L$  with  $\alpha_L$ ; (2) replace  $\alpha_H$  with  $\hat{\alpha}_H$ .

The low-safety type's price, output and profits are unaffected by the presence of naively pessimistic consumer. Without belaboring the point, one can now show that the following proposition holds.

PROPOSITION 4 *Assuming a small fraction of naively pessimistic consumers:*

- (i) When  $c_H > c_L$ : (a)  $\hat{P}_H^s < P_H^s$ ; (b)  $\hat{Q}_H^s > Q_H^s$ ; (c)  $\hat{\Pi}_H^s < \Pi_H^s$ .  
(ii) When  $c_H < c_L$ : (a)  $\hat{P}_H^s > P_H^s$ ; (b)  $\hat{Q}_H^s < Q_H^s$ ; (c)  $\hat{\Pi}_H^s < \Pi_H^s$ .

That is, when costs are increasing in safety level (part (i) in Proposition 4), there is less price distortion when the high-safety type signals safety via price and, since  $\hat{\alpha}_H < \alpha_H$ , items (b) and (c) tell us that the high-safety type's quantity under signaling rises but its profits under signaling fall. Thus, the price reduction more than compensates for the fall in the willingness-to-pay for the high-safety good, so its quantity rises. However, this price reduction also squeezes unit profits, so overall profits for the high-safety type fall. Thus, the high-safety type has a greater incentive to disclose when there are naively pessimistic consumers (in comparison with only skeptical consumers) because the gap between the full-information and signaling profits has thereby increased.

Alternatively, when costs are decreasing in safety level (part (ii) of Proposition 4), again there is less price distortion, but less distortion means a price increase, so the fall in willingness-to-pay is reinforced by the increase in price, causing the equilibrium output level to fall. Here the increase in unit profit is insufficient to overwhelm the output level reduction, so profits under signaling fall. Thus, once again, the high-safety type has an increased incentive to disclose, since the gap between the full-information and signaling profits has increased.

### 5.3 Summary of Naive Consumer Results

The addition of either optimistic or pessimistic consumers (but not both) results in less price distortion. However, in the case of optimistic consumers signaling profits rise, while in the case of pessimistic consumers signaling profits fall. This means that there is a reduced incentive to disclose in the model with optimistic consumers, but a greater incentive to disclose in the model with pessimistic consumers. This is because optimism inflates the willingness-to-pay for the low-safety product, reducing mimicry incentives and relaxing the incentive constraints, thereby raising the high-safety type's profits under signaling, while pessimism deflates the willingness-to-pay for the high-safety product, reducing its profitability under signaling.

## 6 Summary and Conclusions

In this paper, we have considered two channels through which consumers might learn about product safety and how liability influences the use of these channels. First, a firm with private information about the safety of its good might make a credible (but costly) voluntary disclosure. If the firm does not make a voluntary disclosure, then consumers will attempt to infer safety from the product's price. We find that when the firm does not face substantial liability for a consumer's harm (which corresponds to marginal cost increasing in safety), then higher safety is signaled by a price which is distorted upward from its full-information value.

Since disclosure allows the safer type to lower its price and sell more output, it is the safer type that will elect to disclose its safety voluntarily if the disclosure cost is not prohibitive. However, it will do so less often than would be socially optimal, since it considers only the gain in profits and not the accompanying gain in consumer surplus that arises from the lower price and higher output. On the other hand, when the firm does face substantial liability for a consumer's harm (which corresponds to marginal cost decreasing in safety), then higher safety is signaled by a price which is distorted downward from its full-information value. In this case, disclosure would allow the safer type to raise its price and sell less output, which improves its profits but reduces consumer (and total) surplus. Again, it is the safer type that will elect to disclose its safety if the disclosure cost is not prohibitive, but now all disclosure is welfare-impairing.

Mandatory disclosure could be beneficial in some circumstances, though they are quite limited. In part this is because this model recognizes that information will be transmitted through the price if not through direct disclosure. Moreover, the way the information is transmitted through signaling may be socially beneficial, as occurs when the firm distorts its price downward from its full-information monopoly price. This latter result requires that the firm face substantial liability for a consumer's loss (specifically,  $\gamma > k$ ). Of course,  $\gamma > k$  may not hold (even if, *de jure*, there is substantial liability placed on the firm) if there are imperfections in enforcement that shift effective liability back to the consumer. Examples readily come to mind: (1) failure to file; (2) problems of proving causation; (3) difficulties in proving duty or fault; and (4) caps on damage awards. Such difficulties can shift the result to being somewhat more supportive of the circumstances that make mandatory disclosure socially desirable.

We considered the possibility that some fraction of consumers may be naively optimistic (rather than skeptical), and always purchase as if the product were of high safety. This turns out to improve the profits of both low-safety and high-safety types. A low-safety type is better off because naively optimistic consumers demand more at the same price than do skeptical consumers (who recognize that the firm's product is of low safety). A high-safety type is better off because the improvement in low-safety profits reduces the low-safety type's incentive to mimic the price of the high-safety type, which allows the high-safety type to distort its price less (either upward or downward, as dictated by the cost configuration) from its full-information price. Thus, the firm's response to naively-optimistic consumers is to engage in less disclosure; the low-safety type still has no incentive to disclose while the high-safety type's incentive to disclose is reduced.

We then contrasted this with the possibility that some fraction of consumers may be naively pessimistic (rather than skeptical), and always purchase as if the product were of low safety. This turns out to leave low-safety profits unaffected but reduces the profits of the high-safety type. Pessimistic consumers have two effects on the high-safety type's profits. The direct effect is to reduce the consumer's willingness-to-pay for the high-safety product, which tends to reduce profits. The indirect effect is to allow the firm to move its signaling price closer to its full-information price, which tends to increase profits. The direct effect dominates the indirect effect, so that pessimistic consumers ultimately result in

lower signaling profits for the high-safety type. Consequently, its incentives to disclose are enhanced, since the gap between the full-information and signaling profits has increased.

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