Competition and Confidentiality:
Signaling Quality in a Duopoly When There is Universal Private Information

Andrew F. Daughety*
Jennifer F. Reinganum*

Department of Economics
and Law School
Vanderbilt University
Nashville, TN 37235

andrew.f.daughety@vanderbilt.edu, (615) 322-3453, (615) 343-8495 (FAX)
jennifer.f.reinganum@vanderbilt.edu, (615) 322-2937, (615) 343-8495 (FAX)

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ABSTRACT

We model non-cooperative signaling by two firms that compete over a continuum of consumers, assuming each consumer has private information about the intensity of her preferences for the firms' respective products and each firm has private information about its own product's quality. We characterize a symmetric separating equilibrium in which each firm's price reveals its respective product quality. We show that the equilibrium prices, the difference between those prices, the associated outputs, and profits are all increasing functions of the *ex ante* probability of high safety. If horizontal product differentiation is sufficiently great then equilibrium prices and profits are higher under incomplete information about quality than if quality were commonly known. Thus, while signaling imposes a distortionary loss on a monopolist using price to signal quality, duopolists may benefit from the distortion as it can reduce competition. Finally, average quality is lower since signaling quality redistributes demand towards low-quality firms.

JEL Classification Codes: D43, D82, K13, L15.

1. Introduction

How does the need to signal quality through price affect equilibrium pricing and profits, when a firm faces a similarly-situated rival? In this paper, we provide a model of non-cooperative signaling by two firms that compete over a continuum of consumers. We characterize a symmetric separating equilibrium in which each firm's price reveals its respective product quality, and we indicate how crucial parameters affect the price-quality relationship. Finally, we describe circumstances under which the firms are better off for having to signal quality through price (as compared to an informational regime in which their qualities are exogenously known by competitors and by consumers). This contrasts with the results for a monopoly model, in which the usual signaling distortions are disadvantageous to the firm.

We assume "universal incomplete information;" by this, we mean that each market participant has some private information. Each consumer views the products as imperfect substitutes; all else equal, some consumers will prefer one firm's product while other consumers will prefer that of the firm's rival. Each consumer has private information about the intensity of her preference for the firms' respective products. We assume that each firm has private information about its own product's quality. To the best of our knowledge, signaling quality with this information structure has not been addressed previously in the literature; a more detailed discussion of this literature is provided below.

While we focus mainly on a model in which the quality attribute is safety (so that the legal system is brought into play), a particular specification of parameters yields a common model from the industrial organization literature in which quality is interpreted as the probability that a consumer will find the good satisfactory (as in Milgrom and Roberts, 1986).[1] In the product safety context, we view private information on the part of firms as arising through the use of confidential settlements. Daughety and Reinganum (2005a) provide a two-period model in which a single firm produces and sells a product in each period, and then observes the number of units that fail, causing harm. Assuming that consumers harmed in period one negotiate confidential settlements, consumers in the second period know that the firm has private information about its product's safety.

We view confidentiality as having several effects; some of these effects arise in the single-firm context, while others arise only in the multi-firm context. First, a direct effect of confidentiality (which usually results in a blanket gag order issued by a court) is that it prevents plaintiffs from learning about each other's cases and possibly sharing information that might improve the viability of their cases (see Hare, et. al., 1988; they argue that this is an important reason for defendants to seek confidentiality). Thus, confidentiality may reduce the viability of contemporaneous suits. Second, as indicated above, a firm that has settled previous lawsuits confidentially will have private information (both relative to current consumers and relative to its rival) about its product's safety. In this case, consumers will attempt to draw an inference about the firm's product's safety from its price; that is, the firm's price may be used to signal its product's safety. Finally, since the firm observes neither the intensity of the consumer's preference for its product (versus that of its rival) nor its rival's product's safety, the firm must charge all consumers the same price and must make its pricing decisions based upon its own product's safety and upon its conjectures about the rival firm's price-safety strategy. Of course, these conjectures must be correct in equilibrium.

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[1] In a subsequent paper (Daughety and Reinganum, 2005b), we extend the analysis of the consumer satisfaction model to the case of n firms facing a representative consumer with linear, downward-sloping demand.

We find that, for the two-type model presented below, there exists an (essentially) unique symmetric separating perfect Bayesian equilibrium (we restrict attention to symmetric separating equilibria), in which high quality is revealed by a high price. Although it is typical in monopoly signaling models that a separating equilibrium depends only on the support of the distribution, in this case uncertainty about the other firm's type will introduce distribution-dependence into the equilibrium price function.[2] We find that the *interim* prices (that is, the price that would be charged by a firm which knows its own type, but not that of the rival firm), as well as the difference between these type-specific prices, are increasing functions of the prior probability of high quality, as is the *ex ante* expected price. In addition, the *interim* profits (that is, the profits for a firm which knows its own type, but not that of the rival firm) are also increasing in the prior probability of high quality. Although we are unable to establish such a general property for *ex ante* expected profits, we show that *ex ante* expected profits are higher when the firms need to signal their qualities (compared to an informational regime in which their qualities are exogenously known by consumers), if the prior probability of high quality is sufficiently high or the extent of horizontal product differentiation is sufficiently large. This can occur because signaling involves prices that are distorted upwards; while this distortion is disadvantageous for a single firm, non-cooperative price-setting firms charge higher prices (though less than those at the joint maximum) than they would under full information.[3] Thus,

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[2] Some exceptions in the literature considering signaling by one firm do exist. See Matthews and Mirman (1983), wherein an intervening demand shock prevents prices from being fully-revealing (and hence the prior is important in updating beliefs), and Daughety and Reinganum (1995, 2005a), in which distribution-dependence occurs due to a prior R&D decision that makes the type space endogenous.

[3] In our model, firms' types are determined by Nature. In another strand of the price-quality literature (dating back to the early 1980's; see, e.g., Klein and Leffler, 1981), firms choose their qualities, as well as their prices, while consumers observe only the prices. Equilibrium is

the need to signal constitutes a credible commitment to distort prices upward, which can be advantageous for non-cooperative firms.[4]

Related Literature

There are several strands of related literature. Although these papers often address broader issues, we focus here on their implications for price-quality signaling. One relevant body of work is the industrial organization literature on price as a signal of quality. Bagwell and Riordan (1991) provide a monopoly model in which quality may be high or low, with higher quality being produced at a higher unit cost. They show that the low-quality firm chooses its full information price, while the high-quality firm distorts its price upward relative to the full-information price for high quality.[5] Daughety and Reinganum (1995) provide a monopoly model (with a continuum of types) in which quality is interpreted as safety. In this case, when a product fails and harms a consumer, the liability system specifies an allocation of the associated loss across the parties. They show that higher prices signal safer products when the consumer bears a sufficiently high portion of the loss, while lower prices signal safer products when the firm bears a sufficiently high portion of the loss. Hertzendorf and Overgaard (2001a) consider a duopoly model in which consumers do not know either firm's

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characterized by a price premium that is sufficient to induce firms to provide high quality. Thus, unobservable quality relaxes price competition. A recent example is Bester (1998), who relates the magnitude of this effect to the degree of endogenous horizontal product differentiation.

[4] Hertzendorf and Overgaard (2001b, p. 622) make the following observation: "... if prices are strategic complements, a successful separating strategy might dampen the intensity of price competition, resulting in higher profits to both the high-quality and the low-quality firm than in a case of intensive Bertrand Competition between suppliers of products that are perceived as homogeneous by consumers." However, they do not follow up on this issue, nor do they provide an example in which the conjectured effect on profits arises. Their paper is discussed in more detail below.

[5] Bagwell (1992) conducts a related analysis of a monopolist producing a product "line."

quality, but *both firms know both firms' qualities*. Consumers view the products as perfect substitutes (if their prices and qualities were the same), and production costs are assumed to be quality-independent. The model has a large number of candidates for equilibrium, and the paper's focus is on selecting among them using various refinements.[6]

Several papers consider price and advertising jointly as a signal of quality; while we consider only price signals, these papers often have equilibria which involve only price signals. Milgrom and Roberts (1986) provide a monopoly model in which quality may be high or low, the cost of high quality may be higher or lower than that of low quality, and repeat sales are an important attribute of the model. They identify various conditions under which high quality may be signaled with a high price alone, a low price alone, or a combination of price and advertising expenditure.[7] Hertzendorf and Overgaard (2001b) and Fluet and Garella (2002) examine very similar duopoly models in which firms use price and, possibly, advertising expenditure, to signal their qualities. While consumers do not know either firm's quality, again *both firms know both firms' qualities*.[8] Moreover, consumers do not have a preference between the two goods, provided they are of the

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[6] This refinement process ultimately yields an equilibrium in which firms charge a price equal to marginal cost independent of their quality or that of their rival.

[7] Hertzendorf (1993) argues that, if advertising is stochastically-observed, price and advertising expenditure will never be used in combination. Another interesting paper is Linnemer (1998), in which a firm uses price and advertising to signal to two different audiences: it signals its product quality to consumers and its marginal cost to a potential entrant. Since the firm wants to signal high quality via a high price and low cost via a low price, in equilibrium the price may be either higher or lower than the full information price. When the equilibrium price is distorted upward, advertising expenditure may be used to signal low cost.

[8] Harrington (1987), Bagwell and Ramey (1991), and Orzach and Tauman (1996) consider limit pricing models in which two or more incumbent firms with *common* private information about production costs attempt to deter entry using price as a signal of cost. These papers are more closely-related to the models of Hertzendorf and Overgaard, and Fluet and Garella, than to ours.

same quality and charge the same price (i.e., there is no horizontal differentiation). They find that price alone can signal quality when vertical differentiation is substantial, but otherwise advertising is required as well. When advertising is not used, quality is signaled with upward-distorted prices, but when advertising is used, prices may be driven below their full-information levels. Since firms know each other's types, fully-revealing equilibrium strategies are independent of the prior probability of a high type.

Our model also involves a duopoly in which firms use price to signal product quality, but it differs from those models described above in two important respects. First, consumers regard the products as being differentiated horizontally as well as (potentially) vertically. Horizontal product differentiation is important because sufficient differentiation ensures that price-cost margins and output levels are always strictly positive. Thus, we do not need to consider boundary solutions which could arise if the products were extremely close substitutes. Furthermore, several of the comparisons between equilibrium values and their full-information counterparts turn on the magnitude of the parameter reflecting product differentiation. For instance, we find that equilibrium prices and profits are higher under incomplete information than under full information when the extent of product differentiation is sufficiently great. Second, each firm's quality is its private information; we believe that this latter assumption is more realistic than assuming that the firms know each others' quality (especially in the context of safety attributes which are unknown due to the use of confidential settlements), and causes the separating equilibrium price function to be dependent upon the prior probabilities of the types.

There is also a small literature on non-cooperative signaling when each firm has private information about its cost of production. The most closely-related paper is Mailath (1989), which provides an n-firm oligopoly model with linear demand and constant marginal costs in which firms produce horizontally-differentiated products and engage in non-cooperative price competition across two periods.[9] A firm's first-period price can signal its (privately observed) marginal cost of production, which influences its rivals' pricing behavior in the second period.[10] Consumers have no inference problem, since they care only about prices, not marginal costs. Mailath finds that firms' prices are upward-distorted; thus, the desire to signal high costs provides a credible commitment to price higher. He also finds that welfare is lower relative to a "non-signaling benchmark," which retains incomplete information in the first period, but assumes that the firms' types are revealed exogenously prior to the second period (so the signaling motive is removed). Gal-Or (1988) also considers a two-period model in which firms learn about their costs, and those of their rivals, over time. However, she specifically eliminates the signaling problem by assuming that firms do not have private information about their marginal costs prior to choosing their first-period prices. Although we also use a horizontally-differentiated-products model with linear demand and constant marginal costs, our model differs from those above in other ways. First, we consider a one-period model wherein each firm signals its quality to consumers, rather than to its rivals. Second, a firm's product quality (type) affects both its constant marginal cost of production and the demand curve

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[9] Mailath (1988) establishes conditions guaranteeing the existence of separating equilibria in abstract two-period games with simultaneous signaling.

[10] In a similar vein, Martin (1995) considers a two-period model in which two incumbent firms signal their privately known marginal costs, both to each other and to a potential entrant. When firms use price strategies in a horizontally-differentiated products model, an incumbent firm would like its incumbent rival to perceive it as high-cost, but this perception also invites entry. This can result in pooling equilibria. Das Varma (2003) considers a model in which the auction of a cost-reducing innovation precedes market competition. When firms compete in price strategies, each firm bids less aggressively for the innovation in order to persuade its rivals that, should it win the auction, it will be a softer competitor in the subsequent market.

it faces, because product quality also reflects vertical differentiation. Finally, in our model the non-signaling benchmark is the full-information outcome in which both rivals and consumers observe product quality directly. Like Mailath, we find that there are circumstances under which equilibrium prices are upward-distorted relative to our (full-information) benchmark prices, and circumstances under which welfare is higher under full information. However, this need not always be the case since confidentiality lowers the costs of using the legal system, which can result in lower prices and higher welfare.

Finally, there is some previous work on the issue of confidentiality in settlement negotiations. Papers addressing the impact of confidential settlement on sequential bargaining by a defendant facing a series of plaintiffs include Yang (1996) and Daughety and Reinganum (1999, 2002). The paper most closely-related to this one is Daughety and Reinganum (2005a), in which a monopolist produces over two periods. Following first-period production, the monopolist learns its product's quality, which is interpreted as the probability that the product does not harm the consumer; thus, quality is a safety attribute. In a regime of confidentiality, the firm settles lawsuits with harmed consumers confidentially; this (potentially) reduces the viability of suits and prevents consumers from learning product safety. In the second period, the firm has the option to replace an input, thus drawing a new level of safety, or to retain it, thus maintaining the current safety level. Second-period consumers know that the firm has private information about safety, and thus they adjust their beliefs based on observing that the input was retained and based on the second-period price. As a consequence, consumers confront higher prices with a lower probability of purchase. Thus, although confidentiality lowers the firm's expected liability costs, it also depresses demand for its product. That paper also characterizes when this trade-off induces the firm to prefer confidentiality versus a regime of openness (in which suits cannot be settled confidentially, and thus consumers also learn the firm's product's safety). Alternatively put, in the monopoly case, the firm trades off the distortionary losses due to signaling type with the advantages of suppressing lawsuits; when confidentiality is only weakly efficient at suppressing lawsuits, distortionary losses overwhelm any such advantage, and therefore the monopolist has a positive demand for credible auditing of "openness" (that is, the monopolist is willing to pay for an external auditor to assure consumers that confidential settlement is not employed by the firm).

In this paper, we consider the additional effects of confidentiality on firm prices and profits that arise when a firm faces competition from a rival. We find that the disadvantage for a monopolist of a signaling distortion can become an advantage for a duopolist, as the presence of private information may reduce competition between the firms. As mentioned above, the separating equilibrium reflects the prior distribution; this dependence and the need to distort prices upward to signal quality, along with the strategic complementarity of the firms's price strategies, can reduce the intensity of competition between the firms.

We focus on a single period in which (e.g., as a consequence of previous production experience in a regime of confidentiality) each firm is assumed to know its own product safety, but not that of its rival. Consumers are assumed to know their own preferences, but not the safety of either product. Moreover, we assume that if confidential settlement is permitted, then firms cannot commit themselves not to engage in it. However, if confidential settlement were banned, then both firms and consumers would know both products' safety levels.

Confidential settlement is currently permitted (and widely practiced), although with some judicial oversight. One means of ensuring confidentiality is the use of protective orders issued by the court itself; these may keep everything (from initial discovery through final settlement) secret, under pain of court-enforced contempt citations. The other common route is through voluntary dismissal of a suit accompanied by a "contract of silence" which stipulates damages should either party breach confidentiality.[11] Thus, to ban confidential settlement, courts would have to refrain from issuing protective orders, and they would also have to undermine (i.e., refuse to enforce) contracts of silence.[12] Banning confidentiality seems like a formidable task, but the full information case still provides a useful benchmark against which to assess the impact of confidentiality.

Plan of the Paper

In Section 2, we describe the model, including the timing and information structure, the nature of horizontal and vertical differentiation, and the two alternative interpretations of product quality that we will consider (e.g., product safety and consumer satisfaction). In Section 3, we characterize equilibrium prices, outputs and profits under the open and confidential regimes, respectively, and in Section 4 these equilibrium expressions are compared. Finally, Section 5 provides a discussion of potential extensions and conclusions. The Appendix contains the derivation

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[11] See Hare, et. al., (1988), a text for attorneys on obtaining/opposing confidentiality orders; which indicates that seeking such orders in products liability cases is "routine." See the *Manual for Complex Litigation, Third Edition* (1995), section 21.431-432, for details on protective orders (which provide for sealing of discovery and subsequent materials). The *Manual*, which is published by the Federal Judicial Center, is a case management guide for judges. See Garfield (1998) for a discussion of contracts of silence.

[12] Approximately one-fifth of the states (and the federal government) have recently considered "sunshine" laws that would restrict confidentiality if it would significantly endanger public health and safety (leaving much of products liability unaffected). Federal judges in South Carolina recently agreed to eschew confidentiality in "everything from products liability cases to child-molestation claims and medical malpractice suits." See, for example, Collins (2002). Such court-instigated changes, as well as the sunshine laws (with the exception of one enacted in Texas), generally do not apply to unfiled agreements (see Gale Group, 2003). Thus, contracts of silence with penalties for breach are likely to remain enforceable.

of the separating equilibrium and relevant formulae; additional supporting material is in the Supplementary Appendix.[13]

2. Model Structure

We consider an industry comprised of two firms, named A and B, producing products which are horizontally and vertically differentiated, and a continuum of consumers (where the aggregate mass of consumer demand is N). We will contrast decisions made by firms and consumers under each of two possible "regimes" associated with settlement bargaining, one wherein all such bargains are commonly observable to all agents ("open," denoted O), and one wherein the existence and details of the bargain are only known by the parties to the settlement ("confidential," denoted C).

Although we refer to confidential settlements, the use of confidentiality is actually much broader. Sealing orders imposed by a court often involve extensive secrecy; items that are made confidential typically include not only the amount of a settlement, but also any documents and information obtained in pre-trial discovery. In some cases even the names of the parties are made confidential, so that suits simply "vanish" from the record. In the case of private contracts of silence, the case will appear in the record simply as a voluntary dismissal, leaving no indication of whether the case was dropped because it had no merit or because it was settled. Finally, a firm may settle confidentially with an injured consumer before any legal action, such as the formal filing of a lawsuit, is taken. We are taking both regimes to be extreme versions; open settlements are taken as being consistent with common knowledge of the safety level of each firm, while confidential settlements are taken as being consistent with each firm's safety level being private information known by it alone. Note that this means that neither the firm's competitor, nor consumers, know

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[13] http://www.vanderbilt.edu/Econ/faculty/Daughety/C&CSupplementaryAppendix.pdf

a firm's actual safety when the regime is C. In what follows we will use a superscript 'r' to indicate the informational regime.

Timing

This subsection provides a brief overview of the timing of the game; details will be provided in the subsections to follow. There are four stages to the game, denoted 0, 1, 2, and 3. In Stage 0, Nature picks each firm's type, which will reflect vertical differentiation with respect to the safety level associated with the product. Thus, all else equal, vertical differentiation will mean that consumers prefer a product that is safer to one that is less safe. Simultaneously and independently, Nature also picks each consumer's type (which reflects preferences over other attributes of the firm's products, and thereby provides for horizontal differentiation of the products).

In Stage 1, each firm and each consumer learns his type. Furthermore, if the regime is O, each firm's type becomes common knowledge to all agents. Next, but still within Stage 1, firms simultaneously and non-cooperatively choose prices for their products, employing all the information they have. In Stage 2, consumers observe prices, choose a firm from which to buy, and make actual purchases; firms produce to order and thereby incur production costs in this stage. Stage 3 involves use of the products by the consumers, the possibility of harm occurring, and the resolution of any viable lawsuits via settlement.

When we speak of *ex ante* expected values (for example, *ex ante* expected profits), we are performing such computations at the end of Stage 0 and before the beginning of Stage 1. When we speak of *ex post* (or realized) values, we are performing such computations at the end of Stage 2 and before the beginning of Stage 3.[14] Finally, in the C-regime case, wherein each firm must choose prices in Stage 1 without knowing the type of its rival, we will speak of *interim* values (*interim* has no distinctive meaning in the O-regime). As will become clear, the *interim* equilibrium prices for the firms in the C-regime become the realized prices in Stage 2.

Horizontal Differentiation

Each consumer has a preference ordering over the consumption of the two products; horizontal differentiation is captured by assuming that consumers are willing to pay V for one unit of product A, and $V + \gamma$ for one unit of product B, where γ is a consumer-specific incremental value of product B relative to product A. All else equal, some consumers value a unit of product B more highly than they do a unit of product A and some value a unit of product B less highly than a unit of product A; the net value (all else equal) is captured by γ. This incremental value is private information for each consumer and lies in the interval $[-\varepsilon, \varepsilon]$, with $\varepsilon > 0$. Alternatively put, in Stage 0, Nature chooses (for each consumer) a value of γ in the type space $[-\varepsilon, \varepsilon]$, and provides this private information to each consumer in Stage 1. The prior distribution of γ on this interval is common knowledge for all agents and is denoted F; for tractability, we will assume that F is the uniform distribution on $[-\varepsilon, \varepsilon]$, that is, $F(\gamma) = (\gamma + \varepsilon)/2\varepsilon$. We assume that V is always large enough so that the entire market is "covered" (that is, all consumers buy from one firm or the other).

Vertical Differentiation

The two products are differentiated vertically with respect to safety. Use of a product may cause harm, and harm results in losses incurred by the consumer. The probability of accident-free

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[14] In particular, these computations are *ex ante* of product use and any resulting harm and settlement. Thus, Stage 3 is simply an appropriate (post-market-transaction) continuation game.

use of product i, i = A, B, is denoted θ_i, which can take on one of two possible values, θ_H or θ_L, with $1 > \theta_H > \theta_L > 0$; all else equal, any consumer will prefer a product with a higher level of safety (higher θ) to one with a lower level of safety. The effect of this quality attribute (safety) on a consumer is that if she buys a unit of product i and uses it, then with probability $1 - \theta_i$ the consumer will suffer a harm. More precisely, in Stage 0 the type space for each firm is {H, L}, and Nature's choice for each firm follows the commonly-known prior probability $\lambda = \Pr\{\theta_i = \theta_H\}$, i = A, B. Let the *ex ante* expected safety for a firm be denoted μ; that is, $\mu = \lambda\theta_H + (1 - \lambda)\theta_L$. For simplicity, we assume that the unit cost of production is constant in quantity but increasing in the level of safety, so that the marginal cost of producing a unit with safety θ is $k\theta$.

Alternative Stage 3 Continuation Games

Quality as Product Safety

Harm, suit, settlement, and trial create costs and generate losses that the parties must bear. In particular, suppose that it is common knowledge that each harmed consumer (a potential plaintiff, P) suffers an injury in the amount δ, should an accident occur.[15] Assuming that the firm (the potential defendant, denoted D) is strictly liable for the harms it causes, δ is the amount of damages P would receive if successful at trial.[16]

Notice that compensation is determined by the tort system, rather than by *ex ante* contracting between the firm and a consumer. In the case of injury, a firm cannot limit its liability for a consumer's harm through contractual means. Under the penalty doctrine, the common law does not

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[15] Harm may be stochastic, but we assume that it is verifiable at the time of settlement; in this case, δ can be viewed as the expected harm.

[16] This paper takes the liability regime as given.

enforce stipulated damages in excess of expected damages (Rea, 1998, p.24). Thus, the highest enforceable value of stipulated damages would be δ. But then, assuming that the firm cannot commit not to dispute causation (that is, the consumer would still have to present a convincing case in order to have the contract enforced), the consumer's expected loss would be unchanged.

Simply knowing that one has been harmed by the product is not sufficient to win at trial; rather, P must provide convincing evidence of causation, even under strict liability. Therefore, we assume that there is a regime-specific probability, denoted ν^r, r = O, C, that a consumer will be able to provide convincing evidence (i.e., has a "viable" case). With probability 1 - ν^r, other intervening factors may cloud the relationship between product use and harm, undermining the viability of the consumer's case. As mentioned in the Introduction, one effect of confidential settlement is to prevent plaintiffs from learning about each others' cases and sharing information that might improve the viability of their cases. Thus, we assume that $\nu^C \leq \nu^O$. Moreover, we assume that when a consumer complains of harm to the firm, it is common knowledge (between the parties) whether the consumer has a viable case. Thus, a plaintiff with a non-viable case receives nothing, while a plaintiff with a viable case receives a settlement.

Moreover, there are costs of engaging in settlement activity and, if there is trial, there are court costs. In the American system, the costs of negotiation and of trial are borne by the individual parties to the suit. Rather than provide a detailed model in the main text,[17] we simply posit that the expected loss borne by a harmed consumer is given by $L_P(\nu)$ and the expected loss borne by the firm

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[17] The same litigation subgame structure was used in the monopoly model of Daughety and Reinganum (2005a), and this discussion draws heavily on the one in that paper; a synopsis of this subgame is provided in the Supplementary Appendix. For surveys of the settlement literature, see Hay and Spier (1998) and Daughety (2000).

when a consumer is harmed is given by $L_D(\nu)$. To complete the description, assume that $L_P(0) = \delta$, $dL_P(\nu)/d\nu < 0$, $L_P(\nu) > 0$ for all ν, $L_D(0) = 0$, $dL_D(\nu)/d\nu > 0$, $L(\nu) \equiv L_P(\nu) + L_D(\nu)$ is the joint loss, and $dL(\nu)/d\nu > 0$. Thus, increased viability reduces P's uncompensated losses, increases D's expected losses from liability, and increases their joint losses. Finally, let $L_P^r \equiv L_P(\nu^r)$, $L_D^r \equiv L_D(\nu^r)$ and $L^r \equiv L(\nu^r)$ for r = O, C.

Quality as Consumer Satisfaction

A special case of the above subgame corresponds to the industrial organization model in which a firm uses price to signal the quality of an experience good. Quality has often been modeled as the probability that a product performs, but the consumer satisfaction interpretation (which we trace to Milgrom and Roberts, 1986) is somewhat more subtle. Here quality is interpreted as the probability that a consumer is completely satisfied with the product; higher-quality products have a higher probability of consumer satisfaction. Under this interpretation of product quality, it cannot be verified *ex post* whether the product "failed," and therefore a firm cannot offer a warranty (since every consumer would claim dissatisfaction).[18] Thus, the full loss falls on the consumer; when the consumer is dissatisfied with the product, she experiences a loss of δ (relative to V) and there are no transfers from the firm to dissatisfied consumers. This corresponds to the special case of $\nu^C = \nu^O = 0$, resulting in $L_D^r = 0$ and $L_P^r = \delta$, for r = O, C.

[18] If the product's failure were verifiable then a firm could offer a warranty contract specifying the consumer's extent of recovery in the event of product failure. While this warranty version would bear a formal resemblance to the product safety version, the warranty contract should be endogenous (whereas, we have argued, the tort system is exogenous) and thus warranties could serve as another route via which quality could be signaled (see Lutz, 1989, for such a model).

Welfare

The social cost of a unit is the sum of the production costs and the joint expected losses arising from harm. Thus, for regime r, the social cost associated with a unit (of safety θ), $SC^r(\theta)$, is $(1 - \theta)L^r + k\theta$. We focus on the case wherein increasing safety reduces overall social costs and therefore make the following assumption.

Assumption 1: The social cost of a unit (of safety θ), $SC^r(\theta)$ is a decreasing function of θ. The immediate implication is that $L^r > k$, r = O, C. We will also assume (to maintain interiority of the solutions) that price-cost margins and quantities sold are always positive. We will therefore employ various parameter restrictions, which we will note as they arise.

Social welfare under regime r, when firm A's product provides safety level θ_A and firm B's product provides safety level θ_B, is:

$$SW^r(\theta_A, \theta_B) = N\{\int_{MA}(V - SC^r(\theta_A))f(\gamma)d\gamma + \int_{MB}(V + \gamma - SC^r(\theta_B))f(\gamma)d\gamma\},$$

where $MA = [-\varepsilon, \Gamma^r(\theta_A, \theta_B)]$ is the equilibrium interval of consumers constituting the market for product A, $MB = [\Gamma^r(\theta_A, \theta_B), \varepsilon]$ is the equilibrium interval of consumers constituting the market for product B, and $\Gamma^r(\theta_A, \theta_B)$ is the equilibrium marginal consumer (the consumer who is just indifferent between products A and B, given equilibrium prices chosen by the firm). This marginal consumer, whose identity also depends upon the regime, is found in equilibrium, since prices set in Stage 1 act to sort consumers into those who choose to buy product A and those who choose to buy product B. Note that $(\varepsilon + \Gamma^r(\theta_A, \theta_B))/2\varepsilon$ is the proportion of the interval $[-\varepsilon, \varepsilon]$ associated with purchase of product A; that is, firm A's product "captures" more (less) of the market than firm B's product as $\Gamma^r(\theta_A, \theta_B)$ is greater (less) than 0.

Other Notational Conventions

Lower case letters will be used to designate (un-optimized, or random values of) variables such as prices, output levels, and profits, possibly as a function of other variables (for example, Stage 2 profits before prices are picked). Equilibrium values of variables will be indicated by capital letters and will exploit the symmetry inherent in the model. *Ex ante* expected equilibrium variables will only carry the supercript for the regime (for example, the *ex ante* O-regime profit for a firm is denoted as $E_\theta[\Pi^O]$). *Interim* equilibrium values of variables will have a subscript indicating firm type (for example, P_L^C is the equilibrium price posted by an L-type firm in the C-regime). *Ex post* values of the variables will have a superscript indicating regime and two subscripts (s and t): the first subscript indicates a firm's type and the second subscript indicates that firm's rival's type. Thus, Q_{HL}^O denotes the output for a firm producing a high-safety product and facing a rival producing a low-safety product, under the O-regime. Furthermore, at some intermediate steps of the analysis, a subscript i or j will be used to indicate firm name (as opposed to firm type), when this acts to clarify the role of rivalry and will not cause confusion with firm type. Finally, A's (B's) type is θ_A (θ_B), but we will also use the notation that a firm's type is θ_s and its rival's type is θ_t, where s and t can be H or L; for example, $\theta_B = \theta_L$ means that firm B is an L-type firm.

3. Regime-Specific Results

Analysis When Product Safety is Common Knowledge

In this analysis the regime is r = O, so that the safety levels of the two products are common knowledge before pricing and purchasing of output occurs. Given the prices p_A and p_B, a consumer of type γ will buy one unit of product A if:

$$V - (p_A + (1 - \theta_A)L_P^O) \geq V - (p_B + (1 - \theta_B)L_P^O) + \gamma;$$

otherwise he will buy one unit of product B. Thus, for any pair of prices p_A and p_B, the marginal type of consumer is $\gamma^O = p_B - p_A - (\theta_B - \theta_A)L^O_P$. Hence, the aggregate demand for product A when settlements are open, denoted $q^O_A(p_A, p_B, \theta_A, \theta_B)$, is $NF(p_B - p_A - (\theta_B - \theta_A)L^O_P)$ and the aggregate demand for product B, denoted $q^O_B(p_A, p_B, \theta_A, \theta_B)$, is $N[1 - F(p_B - p_A - (\theta_B - \theta_A)L^O_P)]$. Using our assumption that F is the uniform distribution, this means that $q^O_A(p_A, p_B, \theta_A, \theta_B) = N[\varepsilon + p_B - p_A - (\theta_B - \theta_A)L^O_P]/2\varepsilon$ while $q^O_B(p_A, p_B, \theta_A, \theta_B) = N[\varepsilon + p_A - p_B - (\theta_A - \theta_B)L^O_P]/2\varepsilon$. Note that the aggregate demand for each product is downward-sloping in its own price and its rival's safety level, and upward-sloping in its rival's price and its own safety level, and that the firms' demand functions are symmetric. Thus, firm i's profit, denoted $\pi^O_i(p_A, p_B, \theta_A, \theta_B)$, i = A, B, is:

$$\pi^O_i(p_A, p_B, \theta_A, \theta_B) \equiv p_i q^O_i - (1 - \theta_i)L^O_D q^O_i - k\theta_i q^O_i,\ i = A, B.$$

Results of the Analysis under the O-Regime

The equilibrium prices, aggregate quantities and profits (for given θ_A and θ_B) are detailed in the following proposition; as indicated earlier, let P^O_{st}, Q^O_{st}, Π^O_{st} be (respectively) the equilibrium price, quantity and profit for a firm of type s, facing a rival of type t.

<u>Proposition 1</u>.

i) The full information (O-regime) *ex post* equilibrium prices, quantities and profits for a firm with safety level θ_s (s = L, H) facing a rival with safety level θ_t (t = L, H) are as follows:

$$P^O_{st} = (1 - \theta_s)L^O_D + k\theta_s + \varepsilon + (\theta_s - \theta_t)(L^O - k)/3,$$

$$Q^O_{st} = N(\varepsilon + (\theta_s - \theta_t)(L^O - k)/3)/2\varepsilon,$$

and $$\Pi^O_{st} = N[\varepsilon + (\theta_s - \theta_t)(L^O - k)/3]^2/2\varepsilon.$$

ii) Each firm's *ex ante* expected price, denoted $E_\theta[P^O]$, is:

$$E_\theta[P^O] = (1- \mu)L^O_D + \mu k + \varepsilon.$$

iii) Each firm's *ex ante* expected profit, denoted $E_\theta[\Pi^O]$, is:

$$E_\theta[\Pi^O] = N\varepsilon/2 + \lambda(1 - \lambda)\Delta^2(L^O - k)^2N/9\varepsilon.$$

The equilibrium price for firm i has a nice interpretation: it is the firm's full marginal cost plus an adjustment due to the two forms of product differentiation. The first two terms together comprise the full marginal cost of a unit of good i when firm i's safety level is θ_i; the first term is the firm's expected loss from liability, a downstream cost, while the second term is the marginal cost of physical production of the good, a current cost. The last two terms together reflect the two types of product differentiation, with the first term indicating a mark-up due to horizontal differentiation and the second term providing an adjustment for vertical differentiation. Notice that, since the support of γ is $[-\varepsilon, \varepsilon]$, the greater the extent of horizontal differentiation (ε), the higher the price. The last term is positive (respectively, negative) if the firm's safety level, θ_s, is greater than (respectively, less than) its rival's safety level, θ_t ($t \neq s$). In order that the price-cost margins and the quantities be positive, we require that $\varepsilon > \Delta(L^O - k)/3$, where $\Delta \equiv \theta_H - \theta_L$. Further, a firm's *ex ante* expected profit is increasing and convex in the extent of vertical differentiation (Δ) and in the reduction in social costs that a marginal improvement in safety generates (that is, $L^O - k$). Finally, it is straightforward to compute the equilibrium marginal consumer, $\Gamma^O(\theta_A, \theta_B)$, which is $(\theta_A - \theta_B)(L^O - k)/3$, implying that the firm with the higher safety level has the larger market.

Notice that, for s = L, H and t = L, H:

$\partial P^O_{st}/\partial\theta_s = (2(k - L^O_D) + L^O_P)/3$; $\partial P^O_{st}/\partial\theta_t < 0$;

$\partial Q^O_{st}/\partial\theta_s > 0$; $\partial Q^O_{st}/\partial\theta_t < 0$;

$\partial \Pi^O_{st}/\partial\theta_s > 0$; and $\partial \Pi^O_{st}/\partial\theta_t < 0$.

Thus, a firm's equilibrium quantity and profits are increasing in its own safety level and its equilibrium price, quantity and profits are decreasing in its rival's safety level. The only non-monotonicity concerns the effect of a firm's safety level on its own price; as indicated above, this depends upon the magnitudes of the relative allocation of losses between the consumer and the firm, as well as the per unit marginal production cost of safety. Notice that if L_D^O is less than k, then the firm's price and safety level are positively correlated; a similar consideration will hold true in the incomplete information model below. On the other hand, if (say) losses are large and the firm directly bears a substantial portion of them (i.e., L_D^O is sufficiently greater than k), then the firm's price and safety level will be negatively correlated. This is sensible since, with a high safety level, the firm is unlikely to face many lawsuits, so its overall liability will be low, which means that it can afford to set a lower price so as to sell more of its product. Elsewhere, we have examined these two possibilities in the context of a monopoly (see Daughety and Reinganum, 1995); there we show that both the full information and incomplete information (signaling) price responses to own safety level reflect the allocation of liability between the firm and the consumer, as well as the production cost parameter k. In this paper we emphasize the positive linkage between price and safety, which arises when the firm's full marginal cost is increasing in the safety of its product. Thus, we make the following assumption, which guarantees that $\partial P_{st}^O/\partial\theta_s$ is positive.

Assumption 2. $k > L_D^O$.

Using Proposition 1 and Assumption 2, we find that the prices, quantities and profits are ordered based upon the types of the two firms.

Proposition 2. Full information (O-regime) prices, quantities and profits, as a function of own and rival's types, are ordered as follows.

i) $P_{HL}^O > P_{HH}^O > P_{LL}^O > P_{LH}^O$;

ii) $Q^O_{HL} > Q^O_{HH} = Q^O_{LL} > Q^O_{LH}$;

iii) $\Pi^O_{HL} > \Pi^O_{HH} = \Pi^O_{LL} > \Pi^O_{LH}$.

Notice that price, output level and profit are highest for the high-type firm (and lowest for the low-type firm) in an industry with asymmetric safety. If the firms are symmetric with respect to safety, then profits and quantities are equal since there is no vertical differentiation, but prices still differ because the full marginal cost is increasing in safety-level.

Analysis When Product Safety is Private Information

Assumption 2 implies that $k > L^C_D$, which means that high safety will be signaled by a high price. We assume a further parameter restriction for the analysis to follow. First, to maintain interiority of the realized quantities, we require $\varepsilon > \lambda\Delta L^C_P$. Second, we assume that $\varepsilon > \Delta L^C_P/2$; this is sufficient to guarantee a unique equilibrium price-pair.[19] Together, this means that we assume that $\varepsilon > \max\{\lambda\Delta L^C_P, \Delta L^C_P/2\}$.

Given the timing of the game, only consumers need construct beliefs about firm types, as only they will observe the prices chosen by the firms before taking an action. Since each firm knows only its own type, the consumer's belief about the firm's type depends only on that firm's price. This is because, since firm j does not know firm i's quality (and this fact is common knowledge), firm j's price cannot signal anything about firm i's quality and hence consumers' inferences about firm i's quality should not depend on firm j's price. Fudenberg and Tirole (1991, pp. 332-3) incorporate this restriction (which they refer to as "no signaling what you don't know") into their definition of perfect Bayesian equilibrium for a general class of abstract games of which ours is a special case. By contrast, in the models of Hertzendorf and Overgaard (2001a,b) and Fluet and

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19 Note that this assumption implies the assumption on ε made earlier for the O-regime.

Garella (2002), both firms know both quality levels and hence consumer beliefs depend on both firms' prices.

Therefore, let $\varphi_i(p_i) \in [0, 1]$ denote a representative consumer's posterior belief that product i is of high quality, given the observed price. Moreover, let $b_i(p_i) \in [\theta_L, \theta_H]$ denote the consumer's posterior expected quality for product i, given the observed price. That is, $b_i(p_i) = \varphi_i(p_i)\theta_H + (1 - \varphi_i(p_i))\theta_L$. Then, a consumer of type γ will buy from firm A if:

$$V - (p_A + (1 - b_A(p_A))L_P^C) \geq V - (p_B + (1 - b_B(p_B))L_P^C) + \gamma,$$

and will otherwise buy from firm B. Hence, for any pair of prices p_A and p_B, the marginal type of consumer is $\gamma^C = p_B - p_A - (b_B(p_B) - b_A(p_A))L_P^C$.

We seek to characterize a separating equilibrium. Similar to the earlier derivation under full information, firm A's expected aggregate quantity sold under incomplete information, if it announces price p_A and firm B uses the separating price strategy $p_B(\theta)$, is:

$$q_A^C(p_A, p_B(\theta)) = N\{\lambda F[p_B(\theta_H) - p_A - (\theta_H - b_A(p_A))L_P^C] + (1 - \lambda)F[p_B(\theta_L) - p_A - (\theta_L - b_A(p_A))L_P^C]\}.$$

Again, assuming F is the uniform distribution, this quantity can be written as:[20]

$$q_A^C(p_A, p_B(\theta)) = (N/2\varepsilon)(\varepsilon + E_\theta(p_B) - p_A + (b_A(p_A) - \mu)L_P^C),$$

so that firm A's profits can be expressed as:

$$\pi_A^C(p_A, p_B(\theta)) = (p_A - (1 - \theta_A)L_D^C - k\theta_A)(N/2\varepsilon)(\varepsilon + E_\theta(p_B) - p_A + (b_A(p_A) - \mu)L_P^C).$$

Similarly, firm B's profits can be expressed as:

$$\pi_B^C(p_B, p_A(\theta)) = (p_B - (1 - \theta_B)L_D^C - k\theta_B)(N/2\varepsilon)(\varepsilon + E_\theta(p_A) - p_B + (b_B(p_B) - \mu)L_P^C).$$

Since the firms have symmetric cost and demand functions, and since the prior distribution

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[20] Note that while the approach is, in theory, generalizable to more than two types and alternative distribution functions F, we employ the uniform because it makes computing the actual prices possible, which allows for some of the comparisons below.

over safety level is also the same for both firms, we will focus on the symmetric separating perfect Bayesian equilibrium. This equilibrium is symmetric in the sense that both firms use the same pricing strategy, and each consumer's belief about a firm's type is purely dependent upon the observed price (that is, $\varphi_A(p) = \varphi_B(p)$). The equilibrium is revealing since each firm's price is type-dependant; both firms will post the same price if and only if they have the same type. Moreover, consumers' beliefs should be correct; that is, the equilibrium belief about a firm's type based on its price will be the type that would, in equilibrium, post that price. Thus, we define firm i's profit as a function of its price, p, its actual type, θ, and the posterior expected type that a consumer believes it to be, $\tilde{\theta}$, as:

$$\pi_i(p, \theta, \tilde{\theta} \mid E_\theta(p_j)) \equiv (p - (1 - \theta)L_D^C - k\theta)(N/2\varepsilon)(\varepsilon + E_\theta(p_j) - p_A + (\tilde{\theta} - \mu)L_P^C), \text{ i, j = A, B, i} \neq \text{j.}$$

<u>Definition</u>. A <u>symmetric separating perfect Bayesian equilibrium</u> consists of a pair of prices (P_L^C, P_H^C) and beliefs $\varphi^C(\bullet)$ such that for i = A, B, j = A, B, i≠j:

i) $\pi_i(P_L^C, \theta_L, \theta_L \mid E_\theta(p_j)) \geq \max_p \pi_i(p, \theta_L, \varphi^C(p) \mid E_\theta(p_j))$;

ii) $\pi_i(P_H^C, \theta_H, \theta_H \mid E_\theta(p_j)) \geq \max_p \pi_i(p, \theta_H, \varphi^C(p) \mid E_\theta(p_j))$;

iii) $\varphi^C(P_L^C) = 0, \varphi^C(P_H^C) = 1$;

iv) $E_\theta(p_j) = \lambda P_H^C + (1 - \lambda)P_L^C$.

Requirements (i) and (ii) are incentive compatibility restrictions; in conjunction with (iii), these conditions guarantee a separating equilibrium in which the firm's revealing prices are also best responses to the expected price set by the firm's rival. The technique for finding this equilibrium will be to solve (i) and (ii) for separating equilibrium prices expressed as functions of $E_\theta(p_j)$, and then to employ (iv) to solve for the equilibrium prices.

Results for the Analysis under the C-Regime

The following proposition provides the (essentially) unique refined solution[21] to the above conditions and the implied *interim* quantities; due to their complexity of expression, the *interim* payoffs are displayed in the Appendix. We use the Intuitive Criterion to argue that, conditional on any common conjecture about firm j's strategy (including firm j's equilibrium strategy), the firm i of type H distorts its best response upward by the minimum extent necessary to deter mimicry by its type L alter-ego; this is discussed at greater length in the Appendix.

For convenience, let $\eta \equiv \lambda + ((1 - \lambda)^2 + 4\varepsilon/\Delta L^C_P)^{1/2}$; it is straightforward to show that $\eta > 1$, and that it is increasing in both λ and ε.

Proposition 3.

i) There is an (essentially) unique refined symmetric separating perfect Bayesian equilibrium with prices (P^C_L, P^C_H) and supporting beliefs φ^C as follows:

$P^C_L = (1 - \theta_L)L^C_D + k\theta_L + \varepsilon + \Delta L^C_P\lambda(\eta - 1)/2;$

$P^C_H = (1 - \theta_H)L^C_D + k\theta_H + \varepsilon + \Delta[L^C_P(1 + \lambda)(\eta - 1)/2 + L^C - k];$

$\varphi^C(P^C_L) = 0$ when $p < P^C_H$, and $\varphi^C(P^C_H) = 1$when $p \geq P^C_H$.

ii) The implied *interim* quantities are:

$Q^C_L = N/2 + N\Delta L^C_P\lambda(\eta - 1)/4\varepsilon$ and $Q^C_H = N/2 - N\Delta L^C_P(1 - \lambda)(\eta - 1)/4\varepsilon$.

First, let us consider the equilibrium prices. With a little algebra, it can be shown that P^C_H can be re-expressed as:

$$P^C_H = P^C_L + \Delta L^C_P(\eta + 1)/2. \qquad (1)$$

[21] The qualifier "essentially" appears because while the equilibrium behavior specified in the following proposition is unique, it could be supported by other out-of-equilibrium beliefs.

Thus, higher safety is associated with a higher price. Moreover, equation (1) provides a particularly convenient form for expressing the expected equilibrium price for either firm:

$$E_\theta[P^C] = (1 - \theta_L)L_D^C + k\theta_L + \varepsilon + \Delta L_P^C\lambda\eta \ . \qquad (2)$$

Next, note that the equilibrium *interim* quantities are declining in own-safety level: $Q_H^C < Q_L^C$. Thus, even though $\theta_H > \theta_L$, the equilibrium output to be produced by a firm that knows it is of type H is less than that of a firm which is of type L; as we will see in the comparisons section below, this will have an important implication for average product quality.

It is also worth observing that both separating prices are functions of λ, and therefore are influenced by details of the prior distribution over θ. As shown in the Supplementary Appendix, this is true for all the (*interim*) equilibrium variables of interest, as indicated in the following proposition.

Proposition 4. The separating prices, P_L^C and P_H^C, the difference in the separating prices, P_H^C - P_L^C, the expected price $E_\theta[P^C]$ for each firm, the *interim* quantities, and the *interim* profits are increasing in λ.

Proposition 4 is somewhat surprising because, with respect to the prior, separating equilibria are usually only influenced by the support of the prior (that is, $\{\theta_L, \theta_H\}$). Here, uncertainty about the rival's type introduces dependence on the prior probability of high quality. In particular, we find that as the proportion of H-types increases so do both separating prices, the *interim* quantity a firm plans to produce and the *interim* profits it expects to achieve. This reflects two effects. First, prices are strategic complements, so a higher price on the part of one firm means that the other firm can charge a higher price. Since each firm is best-responding to the expected price of the other firm, anything that will cause that expected price to rise (in this case, the increased likelihood that the rival firm is an H-type) will result in a higher price by the best-responder. This leads to higher profits for the responding firm. Second, this is a separating equilibrium, so higher profits for the H-type firm increase the incentive for the L-type firm to mimic it, which means that the H-type firm must further increase its price so as to maintain within-firm price separation; this is why the gap between the separating prices grows. Thus, a combination of inter-firm strategic interaction and intra-firm (i.e., inter-type) interaction acts to lessen the intensity of competition and to increase prices and profits as λ increases.[22]

Both firms move simultaneously, posting their appropriate separating prices. Consumers then purchase the good from one or the other of the firms. Under complete information, the *ex post* prices are the same as the *interim* prices, but the *ex post* quantities and profits are not the same as their *interim* counterparts. Let Q^C_{st} and Π^C_{st} be (respectively) the equilibrium *ex post* quantity and profit for a firm of type s, facing a rival of type t, in the C-regime. Since the prices are revealing, the types are correctly inferred, so that $Q^C_{st} = N(\varepsilon + P^C_t - P^C_s + (\theta_s - \theta_t)L^C_P)/2\varepsilon$, for s, t = L, H. This means that:

$$Q^C_{HH} = Q^C_{LL} = N/2; \; Q^C_{HL} = N/2 - N\Delta L^C_P(\eta - 1)/4\varepsilon; \text{ and } Q^C_{LH} = N/2 + N\Delta L^C_P(\eta - 1)/4\varepsilon. \qquad (3)$$

Alternatively, using the *interim* prices, the (realized) equilibrium marginal consumer, $\Gamma^C(\theta_A, \theta_B)$, is computed to be $(\theta_B - \theta_A)\Delta L^C_P(\eta - 1)/2$, re-emphasizing the result that the firm with higher safety has the smaller market share. Again, due to their notational complexity we relegate the expressions of the associated *ex post* profits to the Appendix. The proposition below provides the rankings of the

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[22] The best response functions suggest that the same properties would hold if the prior probabilities were firm-specific. More precisely, let λ_i be the probability that firm i is a high type, i = A, B. Then an increase in λ_i results in a best response by firm j to increase its price (since each type of firm j has a best response which is increasing in the expected price firm i will post). Because of strategic complementarity, this price increase by j leads to an increase in firm i's type-specific prices. Clearly an increase in λ_j directly affects firm i's type-specific prices. Thus, firm i's type-specific prices are increasing in λ_i and λ_j.

ex post quantities and profits; the equation determining the cut-point $\bar{\lambda}$, and that it belongs to (0, 1), is shown in the Supplementary Appendix.

Proposition 5. *Ex post* (C-regime) quantities and profits, as a function of own and rival's types, are ordered as follows.

i) $Q^C_{LH} > Q^C_{HH} = Q^C_{LL} > Q^C_{HL}$;

ii) There exists $\bar{\lambda} \in (0, 1)$ such that $\Pi^C_{HH} = \Pi^C_{LH}$ for $\lambda = \bar{\lambda}$. Moreover:

$\Pi^C_{HL} < \Pi^C_{LL} < \Pi^C_{LH} < \Pi^C_{HH}$ for all $\lambda < \bar{\lambda}$ and $\Pi^C_{HL} < \Pi^C_{LL} < \Pi^C_{HH} < \Pi^C_{LH}$ for all $\lambda > \bar{\lambda}$.

Thus, in contrast with the full information version, under the C-regime and asymmetric safety, the firm with the high safety level provides the smaller output level and has the lowest profits; we return to this point below in the section on comparisons between the two regimes.

4. Comparing the Equilibria of the Open and Confidential Regimes

A comparison of the results in the foregoing propositions yields two types of results: global and restricted. Restricted results refer to comparisons that rely on one of three possible restrictions of the parameter region: 1) ε sufficiently large, suggesting results that will hold when the extent of horizontal differentiation is large (i.e., consumers are more likely to view the goods as relatively weak substitutes); 2) ν^C and ν^O are close in value, meaning that confidentiality is weakly effective in reducing the viability of a suit relative to openness (note that this doesn't constrain overall case viability); 3) λ close to one (zero), meaning that there is a high likelihood that both firms are high (low) types.

Global Comparisons

Based on Proposition 1 and the equations displayed in (3), comparing the values and rankings for the realized quantities Q^r_{st} (s = H, L; t = H, L; r = O,C) provides Proposition 6:

Proposition 6.

i) $Q^C_{ss} = Q^O_{ss}$ for s = H or L;

ii) $Q^C_{LH} > Q^O_{LH}$ while $Q^C_{HL} < Q^O_{HL}$.

Thus, relative to an O-regime, output (when types are asymmetric) is skewed towards the L-type firm in the C-regime. This has an immediate application to the *ex ante* average quality of the product placed on the market by the industry.

Corollary 1. The *ex ante* average safety of a unit produced under the C-regime is lower than that produced under the O-regime.

Thus, confidentiality leads to lower average product safety. Elsewhere we have shown that a similar result obtains when there is monopoly provision of safety (see Daughety and Reinganum, 2005a). The difference between the two results is that in the monopoly case, it is the rational response of consumers to the presence of incomplete information that causes them to reduce demand in response to a higher price, which reduces the number of higher-safety products that are sold. In the current paper, the reduction in quality is due to competition between the firms; as the H-type firm distorts its price upward, so as to separate (from its own alter-ego), it shifts demand to the L-type firm; if both firms are of the same type, consumers cannot obtain a better deal at the other firm, so they split evenly between the firms.

Next, let us consider realized profits; using the results in Propositions 1 and 5, and the formulae in the Appendix, we find that confidentiality leads to higher realized profits for all combinations of types except for one.

Proposition 7. For $\lambda \in (0, 1)$, $\Pi^C_{ss} > \Pi^O_{ss}$, s = L or H; and $\Pi^C_{LH} > \Pi^O_{LH}$.

The reason that Proposition 7 does not extend to the profits for an H-type firm facing an L-type rival is suggested by comparing Proposition 2(iii) with Proposition 5(ii): the profit for such a firm is ranked at the top of all alternative combinations of types if the regime is open and at the bottom if the regime is confidential.

The following proposition provides a comparison of realized social welfare for the symmetric cases; since social cost is lower under confidentiality than under openness ($L^C < L^O$), social welfare is higher in the symmetric cases. Analogous to earlier notation, $SW^r_{st} \equiv SW^r(\theta_s, \theta_t)$.

Proposition 8. $SW^C_{ss} \geq SW^O_{ss}$ for s = H or L, with equality only at $\nu^C = \nu^O$.

Restricted Comparisons

Realized-price comparisons between the two regimes (that is, comparisons of realized prices under C and O) and comparisons of *ex ante* expected profits and social welfare between the two regimes can be derived under specific restrictions on the parameter space, as suggested above. We first provide the relevant ordering conditions for the realized prices without parameter restrictions and then summarize our results in a proposition.

Ordering the Realized Prices

Proposition 2(i) indicates that the full information realized prices are ordered as: $P^O_{HL} > P^O_{HH} > P^O_{LL} > P^O_{LH}$. An obvious question is: when does incomplete information result in a firm choosing a higher (type-specific) price than it would under full information? Thus, we provide conditions such that $P^C_L > P^O_{LL}$ (and thus $P^C_L > P^O_{LH}$ as well) and such that $P^C_H > P^O_{HL}$ (and thus $P^C_H > P^O_{HH}$ as well):

$P^C_L > P^O_{LL}$ if and only if $\Delta L^C_P \lambda(\eta - 1)/2 > (1 - \theta_L)(L^O_D - L^C_D)$; (4)

$P^C_H > P^O_{HL}$ if and only if $\Delta[L^C_P(\lambda + 1)(\eta - 1)/2 + L^C - k - (L^O - k)/3] > (1 - \theta_H)(L^O_D - L^C_D)$. (5)

Restricted Comparisons Results

The following propositions provide restrictions on the parameter space that yield sufficient conditions for orderings of prices or profits of interest.

Proposition 9. For fixed $\lambda \in (0,1)$, the *interim* prices are higher than the full information prices if horizontal differentiation is sufficiently great or if confidentiality is essentially ineffective in reducing case viability. That is,

i) there exists ε sufficiently large such that $P^C_L > P^O_{LL}$ and $P^C_H > P^O_{HL}$;

ii) there exists ν^C sufficiently close to ν^O such that $P^C_L > P^O_{LL}$ and $P^C_H > P^O_{HL}$.

Proposition 9 says that confidentiality results in higher prices than would occur under openness when either the extent of horizontal differentiation is great (ε large) or the case viability under confidentiality is close to that under openness. Both conditions are readily derivable from the inequalities provided in (4) and (5) above. Note that the strict inequality in (4) will fail to hold should $\lambda = 0$. This means that conditions can readily exist such that, for example, $P^C_L < P^O_{LL}$. Finally, due to Proposition 4, the relevant realized price distortions (that is, P^C_L - P^O_{LL} and P^C_H - P^O_{HL}) are increasing in λ.

Proposition 10: The firms, *ex ante*, prefer C to O if the prior probability of high quality is sufficiently large or if horizontal differentiation is sufficiently great. That is,

i) for fixed ε and fixed $\nu^C \leq \nu^O$, there exists λ sufficiently large such that $E_\theta[\Pi^C] > E_\theta[\Pi^O]$;

ii) for fixed $\lambda \in (0,1)$ and fixed $\nu^C \leq \nu^O$, there exists ε sufficiently large such that $E_\theta[\Pi^C] > E_\theta[\Pi^O]$.

Proposition 10 considers the *ex ante* profits for a duopolist under the C- versus O-regimes.

When λ is sufficiently large then C is strictly preferred to O. In particular (see the Appendix):

$$\lim_{\lambda \to 1} \{E_\theta[\Pi^C] - E_\theta[\Pi^O]\} = N(\Delta(L^C - k) + (4\varepsilon\Delta L_P^C)^{.5})/2.$$

Thus, when the population is (sufficiently) preponderantly H-types, the difference in C- and O-regime *ex ante* expected profits is positive and increasing in the extent of horizontal differentiation (ε) and in the extent of vertical differentiation (Δ): greater differentiation means greater profits under confidentiality than under openness. Tying this together with earlier results (in particular, Propositions 9 and 7), this preference by firms for C over O arises because confidentiality acts to attenuate competition between the two firms: realized prices are higher than under openness, realized profits are higher for at least three of the four possible configurations of safety levels, and *ex ante* expected profits are higher. Alternatively put, one might expect to see confidentiality play a more significant role in industries producing products with important safety considerations and where there may be other causes of product differentiation (e.g., brand adherence). Moreover, if horizontal differentiation is great enough, then confidentiality means higher profits for the firm in comparison with those obtained under openness.

Recall that in monopoly price-quality signaling models (such as, e.g., Bagwell and Riordan, 1991, and Daughety and Reinganum, 1995), the distortion associated with using price to signal quality reduces profits so that, all else equal, a monopolist would prefer that its quality be observable to consumers. When confidentiality also reduces case viability, this preference for openness is moderated, but a monopolist would prefer an open regime to a confidential one if ν^C were sufficiently close to ν^O (see, e.g., Daughety and Reinganum, 2005a). However, in the current model the upward price distortions associated with using price to signal quality can improve equilibrium profits for the firms, since they relax the intensity of price competition.

Finally, consider the basic tradeoff between the social benefits of confidentiality and its social costs. As indicated in Proposition 8, realized social welfare is higher in regime C when both firms have the same realized type, simply because the social costs of an accident are lower in regime C than in regime O, and all output is produced at the same social cost. However, when the realized firm types are different, there is a reallocation of output toward the low-safety firm (in the C-regime), which tends to reduce realized social welfare. Although no general ranking of realized social welfare across regimes is possible (when realized firm types are different), it is easily shown that realized social welfare is higher in regime O when ν^C is sufficiently close to ν^O. The Appendix provides the formula for $E_\theta[SW^C]$ - $E_\theta[SW^O]$, the difference in *ex ante* expected social welfare between confidential and open regimes, which leads to the following result.

Proposition 11.

(i) Society prefers C to O ($E_\theta[SW^C] > E_\theta[SW^O]$) when, for fixed ε and fixed $\nu^C < \nu^O$, λ is either sufficiently large or sufficiently small.

(ii) Alternatively, society prefers O to C when, for fixed ε and fixed $\lambda \in (0,1)$, ν^C is sufficiently close to ν^O.

Comparing element (ii) of Proposition 11 and Proposition 10, we see that there is a region of the parameter space, wherein ν^C is sufficiently close to ν^O and either λ is high (but not 1) or ε is sufficiently high, such that firms prefer confidentiality and society prefers openness. Of course, society may prefer confidentiality as well if ν^C sufficiently below ν^O means that social costs are reduced sufficiently by confidentiality (due to reducing the viability of cases) to compensate for the effects of confidentiality on prices and the concomitant reduction in average product safety.

The Consumer Satisfaction Model

As discussed in the Introduction, this version of the model assumes that vertical differentiation is measured by (unverifiable) consumer satisfaction with the product. Price is used to signal quality, but now all losses are borne by the consumer ($L_D^r = 0$, r = C, O; $L_P^r = \delta$, r = C, O), where C now simply indicates incomplete information about quality and O indicates complete information about quality. Essentially, we have eliminated Stage 3 of the previous game by setting $\nu^C = \nu^O = 0$.

The results are summarized in the following corollary.

Corollary 2. When quality represents consumer satisfaction, incomplete information:

i) distorts all prices upward;

ii) reduces *ex ante* average product quality;

iii) enhances realized profits for all possible firm configurations except for a high-quality firm facing a low-quality rival;

iv) enhances *ex ante* expected profits when either a) λ is sufficiently large or b) ε is sufficiently large;

v) reduces *ex ante* expected social welfare.

These results again reflect the mutual reinforcement of strategic complementarity between the firms and inter-type (i.e., intra-firm) competition resulting in distortionary pricing to enable signaling. Here, *ex ante* expected social welfare is unambiguously reduced by this distortionary effect, while *ex ante* expected profits are enhanced when either quality is very likely to be high or when the extent of horizontal differentiation is great.

5. Further Observations and Conclusions

We briefly consider the effect of minimum quality regulation on the confidentiality model, discuss some possible extensions and provide a brief summary and conclusions.

Minimum Quality Regulation

We now return to the interpretation of quality as the product's safety level. Since, as shown earlier, average product quality is lower under confidentiality, one might naturally wonder how minimum quality regulation might affect that equilibrium. While a full investigation is beyond the scope of the current paper, a simple examination of the comparative static wherein we marginally increase θ_L is suggestive. The following can be shown:

i) $\partial P^C_H/\partial\theta_L < 0$; $\partial[P^C_H - P^C_L]/\partial\theta_L < 0$;

ii) $\partial Q^C_{LH}/\partial\theta_L < 0$; $\partial Q^C_{HL}/\partial\theta_L > 0$;

iii) $\partial E_\theta[SW^C]/\partial\theta_L > 0$.

Thus, in sum, a small increase in θ_L reduces both the H-type price and the gap between the H- and L-prices, brings asymmetric-safety-level industry outputs closer together, and increases welfare. This is because the increase in θ_L (holding all else constant) reduces the extent of vertical differentiation, and thereby reduces the extent to which prices are distorted (at least for the H-type). This is especially evident since the difference between the *interim* prices decreases as well. Moreover, note that (in the C-regime) increasing θ_L causes the realized quantities to shift so as to reduce the extent to which average product quality falls below that obtained in the O-regime.

Potential Extensions of the Model

There are several issues that we have not explored here, but that are worth exploring. First, we have not considered pooling equilibria, largely because they are frequently not robust to refinement. Second, we have considered only a two-type model; while we expect that qualitatively similar results would obtain with a continuum of types, the solution of such a model is complicated by the lack of a closed-form solution for the pricing problem (even in the monopoly case; see Daughety and Reinganum, 1995, for a characterization). Third, we expect that the model could be extended to allow for n symmetric firms, with similar results. Fourth, we have made parameter assumptions that imply that higher safety is signaled by a higher price but, as we noted earlier (and showed in Daughety and Reinganum, 1995), under alternative parametric assumptions safety may be signaled by a low price (for example, because increased safety significantly reduces expected firm liability costs). In this case, the need to price lower to signal high quality is a credible commitment to lower prices, and strategic complementarity reinforces this effect; we conjecture that prices will be distorted downward, and that expected profits will be lower when safety is unobservable. Finally, a different strategy space could affect some results, though the method of solution should remain applicable. For instance, if the firms choose output rather than price, then incentive compatibility and strategic substitution provide conflicting incentives. If safer products have higher unit costs, then a safer product will signal by restricting output, but if the rival is expected to restrict its output, the firm's best response is to expand output. Similarly, if safer products have lower unit costs, then a safer product will signal by expanding output, but if the rival is expected to expand its output, the firm's best response is to restrict its output. These conflicting incentives do not allow us to make unambiguous conjectures regarding the direction of distortion or the impact on expected profits.

Conclusions

We have provided a model in which two firms, and a continuum of consumers, have private information about their own payoffs; a unique (refined) symmetric separating equilibrium price function is characterized. Although it is typical in monopoly signaling models that only the support of the distribution matters in a separating equilibrium, in this case the prior distribution enters through a firm's expectation about its rival. It is shown that the equilibrium prices, the difference between these type-specific prices, the associated outputs, and profits are all increasing functions of the probability of high safety (λ). Since a high-safety firm charges a high price, if there is a higher chance that the rival has high safety, then there is a higher chance that it will charge a high price; since prices are strategic complements, it is a best response for the firm to raise its price as well.

We have indexed the continuation value of the game, following a consumer purchase, by a parameter ν, which reflects case viability in the product safety application of the model and affects the overall level of losses, as well as their allocation between the firm and the harmed consumer. We argued that confidentiality may reduce case viability, so that $\nu^C \leq \nu^O$ (for the consumer satisfaction version of the model, $\nu^C = \nu^O = 0$). Since each viable case is associated with costs of using the legal system, the total losses associated with an accident are lower under confidentiality.

When ν^C is sufficiently close to ν^O then unobservable quality causes all prices to be distorted upward, and lowers average quality and *ex ante* expected social welfare, but increases *ex ante* expected firm profits (when either the probability of high quality or the extent of horizontal product differentiation is sufficiently high). This latter result is in contrast with monopoly signaling models, wherein the distortion associated with signaling reduces *ex ante* expected profits. Finally, when $\nu^C < \nu^O$, then there are regions of the parameter space wherein *ex ante* expected social welfare is higher under confidentiality. In particular, this occurs when λ is either very high or very low, because in this case welfare-reducing output distortions associated with signaling asymmetric safety levels are very unlikely to occur, and thus the primary effect of confidentiality is to reduce the anticipated costs associated with use of the legal system. As indicated above, we expect that these results are likely to be robust to generalizations such as increasing the number of types and/or firms, but these remain the subject of on-going and future research.

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Appendix

This Appendix provides equilibrium expressions too complex for inclusion in the text, the derivation of the symmetric separating equilibrium price function and the proof of Propositions 3. The proofs of Propositions 4, 5 and 10 and some discussion of the settlement bargaining subgame can be found in a Supplementary Appendix. The proofs of Propositions 1, 2, 6, 7, 8, 9, and 11 follow from straightforward algebraic manipulations and are therefore omitted.

Interim Equilibrium Payoffs in a Confidential Regime

Recall that $\eta = \lambda + ((1 - \lambda)^2 + 4\varepsilon/\Delta L_P^C)^{1/2}$ and that $\eta > 1$ for all $\lambda \in (0, 1)$. For the confidential regime, the equilibrium payoffs at the *interim* stage are given by:

$$\pi_i(P_L^C, \theta_L, \theta_L \mid E_\theta(P^C)) = (P_L^C - (1 - \theta_L)L_D^C - k\theta_L)Q_L^C = (N/2\varepsilon)\{\varepsilon + \Delta L_P^C\lambda(\eta - 1)/2\}^2.$$

$$\pi_i(P_H^C, \theta_H, \theta_H \mid E_\theta(P^C)) = (P_H^C - (1 - \theta_H)L_D^C - k\theta_H)Q_H^C$$

$$= \{\varepsilon + \Delta[L_P^C(1 + \lambda)(\eta - 1)/2 + L^C - k]\}(N/2\varepsilon)\{\varepsilon - \Delta L_P^C(1 - \lambda)(\eta - 1)/2\}.$$

Derivation of the Symmetric Separating Equilibrium Price Function

Recall the function describing firm i's profit as a function of its price, p, its actual type, θ, and the type a consumer believes it to be, $\tilde{\theta}$:

$$\pi_i(p, \theta, \tilde{\theta} \mid E_\theta(p_j)) \equiv (p - (1 - \theta)L_D^C - k\theta)(N/2\varepsilon)(\varepsilon + E_\theta(p_j) - p_A + (\tilde{\theta} - \mu)L_P^C),\ i, j = A, B,\ i \neq j.$$

Define $c_s \equiv (1 - \theta_s)L_D^C + k\theta_s$, s = L, H and $d_t \equiv \varepsilon + E_\theta(p_j) + (\tilde{\theta}_t - \mu)L_P^C$, t = L, H. Then we can use the short-hand notation $\pi_{st}(p) = (p - c_s)(d_t - p)$ to denote the profits of a firm charging p whose actual type is s, and whose perceived type is t. Note that for any given price, it is always more profitable to be perceived as type H, regardless of true type; and for any given price, it is better to be type L, regardless of perceived type. If there were no signaling considerations, then π_{st} would be maximized by $\rho_{st} = (c_s + d_t)/2$, and the resulting profits would be $\pi_{st} = (d_t - c_s)^2/4$. These prices (actually, "best responses" to $E_\theta(p_j)$) are ordered as follows: $\rho_{HH} > \rho_{LH} > \rho_{HL} > \rho_{LL}$. The only non-obvious case is $\rho_{LH} > \rho_{HL}$; this holds if and only if $d_H - d_L > c_H - c_L$, which is ensured by Assumption 1. Note: in order for the price-cost margins and quantities to be positive for all combinations of s and t, we need to maintain assumptions sufficient for all of these profits to be positive; the tightest constraint is $d_L - c_H > 0$. We will verify that this inequality holds under our maintained assumptions on ε.

Our method of deriving the separating equilibrium prices is to first derive a best response function for firm i that reflects the need to signal its type. This will consist of a pair $(\rho_L^C(E_\theta(p_j)), \rho_H^C(E_\theta(p_j)))$. We will then impose the equilibrium condition that $\lambda\rho_H^C(E_\theta(p_j)) + (1 - \lambda)\rho_L^C(E_\theta(p_j)) = E_\theta(p_j)$ and solve for a fixed point. Finally, the resulting solution (denoted $E_\theta[P^C]$ in the text) is substituted into $(\rho_L^C(E_\theta(p_j)), \rho_H^C(E_\theta(p_j)))$ to obtain the equilibrium prices (which are denoted P_L^C and P_H^C in the text).

No firm is willing to distort its price away from its best response (were its type known) in order to be perceived as type L (since this is the worst type to be perceived to be). Thus, if a firm of type L is perceived as such, its best response is ρ_{LL}, which yields profits of $(d_L - c_L)^2/4$. If a firm of type H is perceived as being of type L, its best response is ρ_{HL}, which yields profits of $(d_L - c_H)^2/4$.

However, either firm would be willing to distort its price away from its best response (were its type known) in order to be perceived as type H. Thus, a candidate for a revealing equilibrium must involve a best response for type H that satisfies two conditions. First, it must deter mimicry by the type L firm (who thus reverts to ρ_{LL}); and second, it must be worthwhile for the type H firm to use this price rather than to allow itself to be perceived as a type L firm (and thus revert to ρ_{HL}). Formally, a separating best response for the type H firm is a member of the following set:

$$\{p \mid (p - c_L)(d_H - p) \leq (d_L - c_L)^2/4 \text{ and } (p - c_H)(d_H - p) \geq (d_L - c_H)^2/4\}.$$

The first inequality says that the type L firm prefers to price at ρ_{LL} (and be perceived as type L) than to price at p (and be perceived as type H). The second inequality says that the type H firm prefers to price at p (and be perceived as type H) than to price at ρ_{HL} (and be perceived as type L). Solving these two inequalities implies that the H-type firm's best response belongs to the interval:

$$[.5\{d_H + c_L + ((d_H - c_L)^2 - (d_L - c_L)^2)^{½}\}, .5\{d_H + c_H + ((d_H - c_H)^2 - (d_L - c_H)^2)^{½}\}].$$

This entire interval involves prices in excess of $\rho_{HH} = (d_H + c_H)/2$; thus, the type H firm distorts its price upwards from the best response function it would follow if it were known to be of type H.

Refinement. We have identified an interval of candidates for the type H firm's best response. We now apply the Intuitive Criterion (see Mas-Colell, Whinston and Green, 1995, pp. 470-471, for a discussion of equilibrium domination and the Intuitive Criterion of Cho and Kreps, 1987). It is appropriate to apply this refinement at this stage in the game because, conditional on any common conjecture (common to firm i and consumers) about firm j's strategy (including firm j's equilibrium strategy), what remains is simply a signaling game between firm i's two types and consumers. The Intuitive Criterion says that consumers should infer type H from firm i's price p so long as type H would be willing to charge p, yet mimicry by type L would be deterred, even under this most-favorable inference. Thus, the firm of type H distorts its best response to the minimum extent necessary to deter mimicry by its alter-ego (type L). Formally, this means that if firm i and consumers entertain the same price function for firm j, then firm i can convince consumers that it is of type H by playing the separating best response $\rho_H^C(E_\theta(p_j)) = .5\{d_H + c_L + ((d_H - c_L)^2 - (d_L - c_L)^2)^{½}\}$. As argued above, type L's best response is $\rho_L^C(E_\theta(p_j)) = (d_L + c_L)/2$. Note that $E_\theta(p_j)$ enters these functions through the terms d_H and d_L.

Each type of firm i plays a best response to firm j's separating strategy (which is summarized, for firm i's purposes, by its expected value). Then in a symmetric equilibrium, the equilibrium expected price, which was denoted $E_\theta[P^C]$ in the text, is a solution to the equation:

$$X = \lambda\rho_H^C(X) + (1 - \lambda)\rho_L^C(X). \quad \text{(A1)}$$

Let $Y = X - c_L$ and let $\alpha = \varepsilon + L_P^C[.5(\theta_H + \theta_L) - \mu]$. Then equation (A1) becomes

$$Y = \varepsilon + \lambda[2\Delta L_P^C(Y + \alpha)]^{1/2}. \tag{A2}$$

Let $Y \geq 0$ be the domain ($Y < 0$ implies that $E_\theta[P^C] < c_L$, which could not be part of an equilibrium since it implies that the firm has a negative price-cost margin in at least one state of the world). Moreover, to ensure that the expression under the square root sign is positive, we assume that $\alpha > 0$; a sufficient condition for $\alpha > 0$ for all $\lambda \in (0, 1)$ is: $\varepsilon > \Delta L_P^C/2$. This sufficient condition is sometimes stronger than necessary, but it is parsimonious. Next, let $W = [2\Delta L_P^C(Y + \alpha)]^{1/2}$; thus, W must be a positive number. Then (A2) becomes:

$$W^2 - W\lambda 2\Delta L_P^C - (\alpha + \varepsilon)2\Delta L_P^C = 0. \tag{A3}$$

This equation has a unique positive root given by $W^* = \Delta L_P^C\eta$, where η is as defined at the beginning of this Appendix. Thus, reversing the sequence of substitutions, we obtain:

$$E_\theta[P^C] = (1 - \theta_L)L_D^C + k\theta_L + \varepsilon + \lambda\Delta L_P^C\eta.$$

Moreover, it can be shown that the assumption $\varepsilon > \Delta L_P^C/2$ ensures that $d_L - c_H > 0$ for all $\lambda \in (0, 1)$.

Finally, we substitute $E_\theta[P^C]$ into $(\rho_L^C(\bullet), \rho_H^C(\bullet))$ to obtain:

$$P_L^C = (1 - \theta_L)L_D^C + k\theta_L + \varepsilon + \Delta L_P^C\lambda(\eta - 1)/2$$

$$P_H^C = (1 - \theta_H)L_D^C + k\theta_H + \varepsilon + \Delta[L_P^C(1 + \lambda)(\eta - 1)/2 + L^C - k].$$

Proof of Proposition 3. We have restricted attention to symmetric separating equilibria, and we have identified a unique (refined) candidate. To verify that the strategies and beliefs do provide a separating equilibrium, suppose that firm j plays the strategy (P_L^C, P_H^C) given above, with expected value $E_\theta[P^C]$, and that consumers maintain the beliefs: $\varphi^C(p) = 0$ when $p < P_H^C$, and $\varphi^C(p) = 1$ when $p \geq P_H^C$. Then, by construction, the type L firm i would be unwilling to charge a price at or above P_H^C (which is equal to $\rho_H^C(E_\theta[P^C])$ in order to be taken for type H. Rather, it will prefer to be taken for type L and to charge the price P_L^C (which is equal to $\rho_L^C(E_\theta[P^C])$). On the other hand, the type H firm i would be willing to charge a price at or somewhat above P_H^C (which is equal to $\rho_H^C(E_\theta[P^C])$ in order to be taken for type H, but among these it prefers the lowest; that is, P_H^C. The consumers' beliefs are correct in equilibrium, and $E_\theta[P^C] = \lambda P_H^C + (1 - \lambda)P_L^C$. QED

Realized Equilibrium Profits in a Confidential Regime

For the confidential regime, the realized equilibrium profits are given by: $\Pi_{st}^C = (P_s^C - (1 - \theta_s)L_D^C - k\theta_s)Q_{st}^C$, s, t = L, H.

$$\Pi_{HL}^C = \{\varepsilon + \Delta[L_P^C(1 + \lambda)(\eta - 1)/2 + L^C - k]\}(N/2\varepsilon)\{\varepsilon - \Delta L_P^C(\eta - 1)/2\}.$$

$$\Pi_{LL}^C = \{\varepsilon + \Delta L_P^C\lambda(\eta - 1)/2\}(N/2).$$

$$\Pi_{LH}^C = \{\varepsilon + \Delta L_P^C\lambda(\eta - 1)/2\}(N/2\varepsilon)\{\varepsilon + \Delta L_P^C(\eta - 1)/2\}.$$

$\Pi^C_{HH} = \{\varepsilon + \Delta[L^C_P(1 + \lambda)(\eta - 1)/2 + L^C - k]\}(N/2).$

The price-cost margins are clearly positive; the only problematical realized quantity is Q^C_{HL}, and a necessary and sufficient condition for this to be positive is: $\varepsilon > \lambda\Delta L^C_P$.

Comparison of Ex Ante Expected Profits Across Regimes

Recall that $E_\theta[\Pi^C] = \lambda\pi_i(P^C_H, \theta_H, \theta_H \mid E_\theta(P^C)) + (1 - \lambda)\pi_i(P^C_L, \theta_L, \theta_L \mid E_\theta(P^C))$ or, alternatively, $E_\theta[\Pi^C] = \lambda^2\Pi^C_{HH} + (1 - \lambda)^2\Pi^C_{LL} + \lambda(1 - \lambda)(\Pi^C_{HL} + \Pi^C_{LH})$. This expression is easily-constructed using the expressions for Π^C_{st}, s, t = L, H given above. Similarly, $E_\theta[\Pi^O] = \lambda^2\Pi^O_{HH} + (1 - \lambda)^2\Pi^O_{LL} + \lambda(1 - \lambda)(\Pi^O_{HL} + \Pi^O_{LH})$ is easily-constructed using the formulae in Proposition 1 in the text. The difference in *ex ante* expected profits (and the limit as $\lambda \to 1$) are given by:

$$E_\theta[\Pi^C] - E_\theta[\Pi^O] = \lambda^2[\Pi^C_{HH} - \Pi^O_{HH}] + (1 - \lambda)^2[\Pi^C_{LL} - \Pi^O_{LL}] + \lambda(1 - \lambda)[(\Pi^C_{HL} + \Pi^C_{LH}) - (\Pi^O_{HL} + \Pi^O_{LH})].$$

$$\lim_{\lambda\to1} \{E_\theta[\Pi^C] - E_\theta[\Pi^O]\} = \lim_{\lambda\to1} \{\varepsilon + \Delta[L^C_P(1 + \lambda)(\eta - 1)/2 + L^C - k]\}(N/2) - N\varepsilon/2$$

$$= N(\Delta(L^C - k) + (4\varepsilon\Delta L^C_P)^{.5})/2.$$

Comparison of Ex Ante Expected Social Welfare Across Regimes

Let $y \equiv (L^O - k)\Delta/3$ and, as above, let $x \equiv \Delta L^C_P(\eta - 1)/2$. Then:

$$SW^O_{HH} = N[V + \varepsilon/4 - SC^O(\theta_H)] \leq N[V + \varepsilon/4 - SC^C(\theta_H)] = SW^C_{HH},$$

$$SW^O_{LL} = N[V + \varepsilon/4 - SC^O(\theta_L)\} \leq N[V + \varepsilon/4 - SC^C(\theta_L)] = SW^C_{LL},$$

with equality only if $\nu^C = \nu^O$. These inequalities follow directly from the fact that the social costs of an accident are lower in regime C than in regime O, since the O regime relies more heavily on the legal system, which is costly.

$$SW^O_{HL} = SW^O_{LH} = N[V - SC^O(\theta_H)(\varepsilon + y)/2\varepsilon - SC^O(\theta_L)(\varepsilon - y)/2\varepsilon + (\varepsilon^2 - y^2)/4\varepsilon].$$

$$SW^C_{HL} = SW^C_{LH} = N[V - SC^C(\theta_H)(\varepsilon - x)/2\varepsilon - SC^C(\theta_L)(\varepsilon + x)/2\varepsilon + (\varepsilon^2 - x^2)/4\varepsilon].$$

Although no general ranking of these expressions is possible, it is easily shown that $SW^C_{HL} < SW^O_{HL}$ as $\nu^C \to \nu^O$. The difference in the *ex ante* expected social welfare under regime C versus O is:

$$E_\theta[SW^C] - E_\theta[SW^O] = \lambda^2[SW^C_{HH} - SW^O_{HH}] + (1 - \lambda)^2[SW^C_{LL} - SW^O_{LL}] + 2\lambda(1 - \lambda)[SW^C_{HL} - SW^O_{HL}].$$

The assertions in Proposition 11 are verified easily, given the expressions above.