

Voluntary Product Safety Certification

Ganesh Iyer,^a Shubhranshu Singh^b

^a Haas School of Business, University of California, Berkeley, Berkeley, California 94720; ^b Carey Business School, Johns Hopkins University, Baltimore, Maryland 21202

Contact: giyer@haas.berkeley.edu (GI); shubhranshu.singh@jhu.edu (SS)

Received: March 24, 2015

Revised: October 7, 2015; February 25, 2016

Accepted: March 5, 2016

Published Online in Articles in Advance:
February 28, 2017

<https://doi.org/10.1287/mnsc.2016.2625>

Copyright: © 2017 INFORMS

Abstract. This paper describes the incentives for firms to seek voluntary product safety certifications. We consider a firm that makes the decision of whether or not to seek certification prior to selling the product. We show that even when the firm and the consumers have the same beliefs about the product's safety, there are incentives for the firm to seek safety certification. The main analysis investigates the role of consumer moral hazard and shows that it can lead to greater incentives for voluntary certification when inherent product safety and effort are substitutes, but smaller incentives when they are complements. The analysis of consumer moral hazard provides a nuanced perspective on the so-called risk compensation or the "Peltzman effect" phenomenon, which postulates higher levels of accidents for safer products. In our paper, products that are successfully certified can end up with a higher incidence of accidents. We also uncover an interesting nonmonotonic relationship between effectiveness of consumers' effort and the firm's incentives to seek certification. Finally, we find that certification can be welfare enhancing in the presence of consumer moral hazard.

History: Accepted by Matthew Shum, marketing.

Keywords: product policy • industrial organization • firm strategy • microeconomic behavior • product safety • certification strategies • information disclosure

1. Introduction

Product safety is a characteristic of the product that determines the likelihood of accidents and potential consumer injury. Safety-related product failures are common. According to Consumer Product Safety Commission (CPSC) estimates based on its National Electronic Injury Surveillance System, about 38.6 million people sought medical attention for injuries related to consumer products between October 2010 and September 2011. These safety failures can impose significant costs on consumers in the form of trauma, disability, lost earnings, and death. The National Safety Council (2013) estimates the economic losses from unintentional safety-related injuries, both fatal and nonfatal, to have been about \$753 billion in 2011.

Given the prevalence of product safety failures, it is natural that consumers care about product safety levels.¹ However, consumers often do not have full information about the safety levels of the products they use. In fact, because safety may depend in a complex manner on the integration of product design, manufacturing, and the environment in which the product is used, it is common for even firms to be uncertain about the extent to which their products are prone to accidents. This would be especially true for new products that have not been in the market for long. Safety certification through independent third-party certifiers such as the American National Standards Institute, ASTM International, and Underwriters Laboratories (UL) is an

important mechanism through which firms can learn about and then communicate the safety of their products to consumers.

Product safety as a characteristic is distinct from product quality in several important ways that are captured in this paper. First, safety failures imply accident and injury to the consumer, which are treated differently by the courts as compared to quality failures that do not involve consumer injury. While the latter is subject to the law of warranty contracts, the former is subject to the law of torts. A firm is only liable for product quality failures if it chooses to offer warranties, and then too the liability is limited to the extent of the warranty. In contrast, for consumer injury from safety failures, a firm is liable for what is referred to as "strict liability," as governed by tort law, which makes safety distinct from product quality. Second, strict liability is imposed on the firm by the court even if the firm had met the minimum safety standards as stipulated by the law. The consumer only needs to prove in the court that an injury was caused during product usage. Third, even under strict liability, the practical reality is that the consumer is often only partially compensated.² Fourth, U.S. consumer product firms are stipulated by law to disclose all known product safety issues and mandatory testing information to consumers. This implies that even when safety is uncertain, consumers and firms are still likely to have symmetric beliefs about the level of product safety. This is especially true

for products that are relatively new and early on in the product life cycle, when the firm does not have the opportunity to accumulate additional safety information available from selling the product over time. In contrast, when there is quality uncertainty, it is more likely that firms have better information about product quality prior to consumer purchase.

Our analysis aims to explain the rationale for the safety certification strategies of firms and captures some important market features. First, there is heterogeneity in firm strategies within an industry and across markets: while some firms voluntarily go through a costly and complex safety certification process, others eschew this process. Even within an industry, certification strategies can differ. For example, in the toy industry, while Fisher-Price does not use third-party safety certification, Disney does. Second, while safety-certified firms can inform consumers about successful certification through a seal or sticker from the certification agency, consumers typically do not know whether the absence of a certification sticker is due to a failed certification attempt or the firm's decision to not seek certification in the first place. This is because most certification agencies do not report a denied certification. Third, the likelihood of a product safety failure may depend not only on its inherent product safety characteristics, but also on the extent to which the consumer exercises care or is negligent while using the product—in other words the extent of consumer moral hazard. For example, consumer moral hazard is important in the automobile industry because the likelihood of an accident depends significantly upon the extent to which the consumer drives safely. The paper examines the manner in which consumer moral hazard affects certification incentives.

In the model, a firm sells a product that is subject to accident with some probability in the hands of the consumer, leading to injury. There is uncertainty about the safety level, and the firm may either be of high or low safety, which implies high or low probability of accident. In the case of an accident, the consumer needs to be compensated by the firm under the strict liability requirement imposed by the court for losses suffered in the accident. As discussed above, the compensation may be partial. The firm first chooses whether or not to seek costly certification from a third-party certification agency. The certification process, while informative of the safety level, is nevertheless imperfect in that it provides better than prior but not perfect information about the firm's safety level. If the firm decides to go for certification and is successful, it gets to use a certification seal that is observable to consumers. Conditional on the outcome of the certification process, the firm chooses the price, and consumers then make inferences about the safety level of product and their purchase decision. Postpurchase, consumers

also decide the extent of care that they want to invest in product usage. Given this framework, we analyze the firm's incentives to voluntarily seek product safety certification.

The first result from the analysis is that the firm can have the incentive to voluntarily seek safety certification even when it has no better information about safety than consumers. This incentive turns on the fact that if consumers do not observe the firm's decision to seek certification, the absence of a safety seal implies that the consumer will be unable to distinguish between a firm that chose not to seek certification and one that did but was denied certification by the third party.

The important results of the paper pertain to how the nature of consumer moral hazard affects certification incentives: Consumer moral hazard leads to greater certification incentives if product safety and consumers' effort are substitutes in the sense that increased consumer effort has a lower marginal effect in reducing accidents for a higher-safety product. In contrast, it leads to lower certification incentives if they are complements (i.e., increased consumer effort reduces accidents to a greater extent for higher-safety products). In the substitutes case, the presence of the certification seal on the product makes consumers less concerned about using the product negligently. In contrast, if safety and effort are complements, it is the absence of the safety certification seal that makes consumers less concerned about using the product negligently. Next, we identify an interesting nonmonotonic effect of the effectiveness of the consumers' effort on the firm's certification incentives. For the substitutes case, the incentive for voluntary safety certification first increases and then decreases with the effectiveness of consumer effort, whereas it is the opposite for the complements case. The nonmonotonicity originates from how the change in the optimal level of consumer effort in using the product with care is affected by the firm's decision to adopt certification as the effectiveness of effort increases.

Our analysis of consumer moral hazard also provides a perspective on what has been termed in the literature as the risk compensation effect or the "Peltzman effect"—which is the idea that consumers may respond to the perceived level of safety and may become less careful if they perceived that a product/activity was made safer, which in turn can lead to greater incidence of accidents when products became safer. While the effect is theoretically sensible, there has been a debate about whether it is empirically significant (see Levitt and Porter 2001). Our analysis provides a more nuanced perspective that is predicated on the certification decisions of firms: Firm certification strategies can rationally make consumers behave as if they were indulging in the risk compensation/Peltzman

effect-like behavior. Consumers may switch from being careful to being negligent in product use when a firm with successful certification induces favorable beliefs about product safety. This is indeed true for the substitutes case; but interestingly, when effort and safety are complements, consumers' response to a more favorable safety belief induced by a successful certification is the opposite of the Peltzman effect—i.e., they become more willing to use the product with care.

Finally, we investigate welfare implications of the voluntary safety certification and find that certification can be welfare enhancing in the presence of consumer moral hazard. This result holds regardless of whether safety and effort are substitutes or complements. The change in the consumers' optimal effort choices in response to certification-generated information about safety drives the increase in welfare. If certification has no effect on consumers' optimal effort choices or if there is no consumer moral hazard, certification leads to lower welfare.

1.1. Related Research

The focus of much of the earlier work on product safety was on the assignment of producer liability. In an initial analysis, Oi (1973) showed that, contrary to conventional wisdom, shifting the liability for accidents from consumers to the firm can lead to increased production of riskier products, because firms are now forced to offer a bundle of the riskier product and a full-coverage insurance policy. Spence (1977) compares the role of producer liability with direct regulation and consumer information provision in promoting safety investments when consumers underestimate the probability of accidents.³ Png (1987) shows that award of damages for loss, tighter negligence standards, and the adoption of a rule under which the loser at trial pays litigation costs of the winner increase the firm's incentive to produce safer products.

The question of whether out-of-court settlement or trial is more effective in promoting safety has also received attention. This question can be seen as the decision to choose ex post (after the accident) openness or confidentiality. Polinsky and Rubinfeld (1988) compare out-of-court settlements to trials and show that when the deterrence effect of trials is taken into account, they may be superior from a policy perspective despite their higher transaction cost. In this vein, Daughety and Reinganum (2005) compare trial vs. settlement but from the firm's perspective. They show that a firm's commitment to openness instead of confidentially settling out of court can be more profitable when the cost of credible auditing to verify openness is sufficiently low. As opposed to this literature, the voluntary-certification decision in our paper can be seen as an ex ante (before the accident) rather than the ex post choice of openness and can therefore affect consumer beliefs about product safety prior to purchase.

Our analysis is related to the product warranties literature under consumer moral hazard and/or asymmetric information. In this context, Cooper and Ross (1985) investigate role of product warranties in the presence of double moral hazard when both firm and consumer effort affect product quality failures, whereas Lutz (1989) analyzes the role of warranties to signal product quality in the presence of consumer moral hazard. Padmanabhan and Rao (1993) examine the effect of consumer moral hazard and heterogeneity in individual risk preferences on the optimal warranty policy, but warranty contracts are less relevant in the context of product safety, because unlike quality failures, any failure in product safety is governed by the strict liability rule according to the law of torts. Further, with consumer moral hazard, the assignment of responsibility in the event of a safety failure depends in the United States on the principle of comparative negligence. Our model formally incorporates these two aspects that characterize product safety-related failures and how they interact with consumer moral hazard. Further, though the consumer effort clearly affects the probability of an accident, there is no paper that we are aware of that considers consumer moral hazard in product safety and the associated role of certification.

This paper is also related to the literature on quality disclosure that originates in Grossman (1981) and Milgrom (1981) and the classic unraveling result that all quality levels are separated and revealed in equilibrium because the highest types in any potential pooling set will have the incentive to reveal their type through disclosure. In marketing, Guo and Zhao (2009) study the effect of competition on the sellers' incentive to disclose quality information. In a policy context, Zhang (2014) examines the implications of policymakers' decision to mandate product content disclosure considering the effect of both transparency of product content and consumer inference of the content quality.⁴

The rest of this paper is organized as follows. Section 2 presents the baseline model. Section 3 introduces consumer moral hazard and presents its implications for the firm's incentives to seek safety certification. Section 4 presents extensions of the baseline model. Section 5 concludes.

2. The Basic Model

Consider a monopolist firm that produces a product that has a safety attribute and whose marginal cost of production is constant and set to zero. Product safety is captured by θ_t , where $t \in \{l, h\}$ represents the type of the firm and whether its product has low or high safety levels. Assume that $1 > \theta_h > \theta_l > 0$. Product safety θ_t is the probability with which the product works without an accident when used by the consumers. Accidents happen with probability $1 - \theta_t$ when a consumer uses

a product of type t ; thus, a high-safety product has a lower accident probability.

At the start of the game, nature moves and draws the firm type from a Bernoulli distribution and assigns it to the firm. The firm has product safety level θ_h with prior probability α , and it is θ_l with the complementary probability. The prior probability distribution is common knowledge. The realized value of θ_t is not known to either the firm or the consumers. When both the consumers and the firm do not know θ_t , they have the symmetric beliefs about product safety. This is the case for many consumer product categories in the United States because firms are stipulated by law to disclose all known safety-related issues to the consumers. Specifically, the Consumer Product Safety Improvement Act (CPSIA) of 2008 requires that all consumer product companies must report potentially unsafe, hazardous, or noncompliant products to the CPSC or face civil penalties. Further, note that all products must meet minimum mandatory safety standards and this information is public. However, products can and do have differing safety performance over and above what is dictated by minimum mandatory standards. Thus, the role of voluntary third-party certification is to potentially produce additional safety information that can help the market distinguish between high- and low-safety products. The firm can choose whether or not to subject itself to a voluntary safety certification and can choose to sell the product to consumers either with or without safety certification.

The certification decision of the firm is denoted by $c \in \{C, NC\}$, where C represents “certification” and NC represents “no certification.” Third-party certification is costly, and the cost is denoted by $k > 0$. The certification process is informative of the product’s safety, but it is imperfect. A firm of a given type is correctly classified as its own type with probability $\rho > 0.5$ and incorrectly classified as the other type with probability $1 - \rho$.⁵ The outcome of certification that is either a “seal” if the firm is found to be of type θ_h or “no seal” if the firm is found to be of type θ_l is represented by $o \in \{S, NS\}$. A firm obviously informs consumers about certification only if the outcome is positive. Therefore, in the absence of a safety-certified seal on the product, the consumers must rationally form beliefs about the certification decision of the firm. After the outcome of the certification stage, the firm sets the price p for the product, and consumers make their purchase decisions. The rationale for the firm to make a certification decision before setting prices is that while certification is a lengthy process and is not easily changeable, prices can be easily changed in the short run once the certification outcome is known to the firm.

The market consists of a unit mass of consumers and each consumer buys at most one unit of the product. The product has basic valuation v that is assumed to

be large enough such that the firm sells the product even if it is denied certification. This assumption rules out a trivial demand based reason for product certification and makes us focus on the more interesting incentive based rationale for the choice of certification: If v is such that the consumer buys a product only if it has a safety seal, then the firm would clearly seek certification for small enough costs. By assuming v to be sufficiently large, we eliminate this obvious incentive for the firm to seek certification. Also, if v is such that the firm does not sell the product when it is denied certification (and consumers believe so) but sells the product otherwise, an incentive for certification is still created. This is because certification creates the option of not selling the product for the firm when beliefs about firm type are unfavorable. In the main analysis, by assuming v to be sufficiently large we eliminate this other reason for certification as well; but in Section 4.3 we present the analysis of the case in which the firm chooses not to sell when it is denied certification.

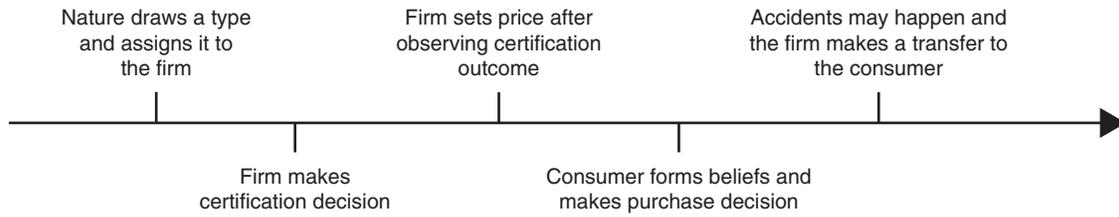
Consumers observe the outcome of certification (if it is positive) and the price before making the purchase decision. They also form beliefs $\lambda(o, p)$ about the certification decision of the firm. The consumer makes her purchase decision $s \in \{0, 1\}$ based on her belief $\mu(\lambda, o, p)$ about the firm’s type, the price charged, and the consumer’s expectation of the uncompensated loss in the event of an accident. We represent by L the full loss to the consumer upon an accident and by L_f the transfer that the firm is stipulated by the court of law to make to the consumer in case of an accident. As already noted, even if the court requires the firm to fully compensate the physical losses, there may still remain uncompensated losses for the consumer; to capture this, we allow $L_f < L$. Thus, the uncompensated losses of the consumer is $L_c = L - L_f$.

We look for the perfect Bayesian equilibrium (PBE) of this game. The equilibrium consists of the beliefs $\lambda(o, p)$ and $\mu(\lambda, o, p)$ of the consumer, the consumer purchase decision $s(\lambda, \mu, p)$, the certification decision of the firm c , and the price set by the firm $p(c, o)$ such that (i) the purchase decision of the consumer maximizes her expected payoff, given her beliefs; (ii) the certification decision and the price maximize the firm’s expected payoff, given consumer’s purchase decision; and (iii) the consumer beliefs are consistent with the firm’s strategy in the equilibrium. A summary of the timing of the model is shown in Figure 1.

2.1. Analysis and Results

Product safety θ_t is uncertain for both the firm and consumers and so both the firm as well as consumers have same ex ante beliefs about product safety. If the firm seeks certification it gets certified as type θ_h with probability $\alpha\rho + (1 - \alpha)(1 - \rho)$. However, with probability $\alpha(1 - \rho) + (1 - \alpha)\rho$ it will be classified to be of type θ_l .

Figure 1. Timing



The consumer observes the outcome of certification (if certification is granted) but not the certification decision of the firm. Consumers will therefore have to form beliefs about the certification decision of the firm and the firm type in deciding whether to purchase the product, and these beliefs will be derived using Bayes’s rule wherever possible. The following proposition describes equilibrium certification strategies.

Proposition 1. *When both the firm and the consumers do not observe the safety level:*

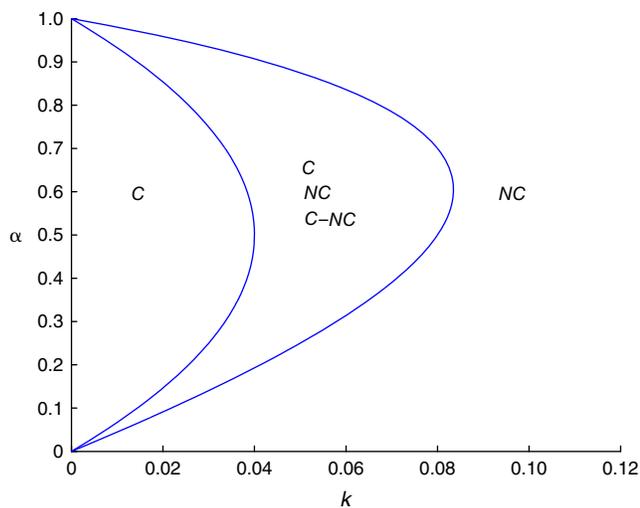
1. If $k \leq (\alpha(1 - \alpha)(2\rho - 1)(\theta_h - \theta_l)L_c)/(\alpha(1 - \rho) + (1 - \alpha)\rho)$, the firm seeks voluntary certification in equilibrium.
2. If $k \geq \alpha(1 - \alpha)(2\rho - 1)(\theta_h - \theta_l)L_c$, the firm does not seek voluntary certification in equilibrium.

The conditions above are also graphically presented in Figure 2. Even if both the firm and consumers have identical beliefs about the safety of the product, a firm may still seek certification in equilibrium. The rationale for this is predicated on the inability of consumers to observe the certification decision of the firm and to detect any deviation in the certification decision. This means that if a firm makes an out-of-equilibrium deviation to no-certification consumers would not be

able to distinguish it from the event that the firm was denied certification. While such a deviation helps the firm to save the certification cost k , it must also now set a lower price that is consistent with the consumers’ belief that the firm could also have been denied certification. This provides the incentive for the firm to seek certification, unless the cost savings from deviation exceeds the loss due to the low price the firm must set upon deviation.

It is intuitive that the certification equilibrium will exist when k is small enough, and no certification for sufficiently large costs. In the intermediate range of k , both the certification and the no certification equilibria exist.⁶ This happens because consumers believe the firm to be high safety with higher probability upon not observing safety seal in the no-certification equilibrium compared to in the certification equilibrium.⁷ The more interesting point is that the firm has smaller incentive to seek certification if the prior belief about the firm having a high-safety product is either too high or too low. If prior beliefs are more extreme, the certification outcome has a lesser effect on ex post beliefs, which means that the price that firm would set does not differ too much between a positive and a negative certification outcome. Seeking certification therefore becomes less attractive. This result may potentially explain the differences between the certification strategies of firms in the toy industry described in the Introduction.

Figure 2. (Color online) Equilibria in k - α Space



Notes. C, NC, and C-NC represent certification, no certification, and mixed strategy equilibrium, respectively. Example for $\rho = 0.7$, $\theta_h = 0.9$, $\theta_l = 0.7$, $L_c = 2$.

3. Consumer Moral Hazard and Safety

In a number of product markets, the likelihood of an accident and injury depends not only on product safety, but also on the extent to which the consumer is careful while using the product. A car rated highly on safety may still end up being more accident prone if driven less carefully by the consumer. We now introduce consumer moral hazard to the basic model and study its effects on the firm’s incentives to seek safety certification. The consumer can either be negligent in using the product, and not incur any cost, or use the product with care by incurring a cost $\kappa > 0$. Negligent use of the product is represented by low consumer effort e_l , while the careful use of the product is denoted by higher consumer effort $e_h > e_l$.⁸

The probability of an accident depends on the effort choice of the consumer and the inherent product safety.

If the consumer uses a product of safety θ_i with care and invests the effort e_h , then accidents happen with probability $1 - \theta_i$. But a negligent use by the consumer increases the likelihood of an accident beyond $1 - \theta_i$. As in a standard moral hazard setup, the firm cannot observe whether or not the consumer put out effort, and so the effort is not contractible. However, in the event of an accident, a court can determine whether or not the consumer was negligent. Consumer effort and product safety could interact in different ways to determine the probability of the accident. In what follows, we examine firm's incentive for certification under two canonical setups: one in which product safety and consumer effort are substitutes and the other in which they are complements.⁹

3.1. The Substitutes Case

Suppose that consumer effort and product safety are substitutes in deciding the probability with which the product works without an accident. By substitutability we mean that the marginal effect of high consumer effort e_h in reducing accident probability is lower for a high-safety product. Suppose that the probability of accident when the consumer is negligent is $(1 - \theta_i) \cdot (1 + \varepsilon)$, whereas it is $(1 - \theta_i)$ if the consumer uses the product with care and puts out the effort e_h . The parameter ε , ($0 < \varepsilon \leq 1$), can be interpreted as the effectiveness of the consumer's effort. A small ε means that consumer effort does not significantly change the probability of accident. The formulation represents the idea that the marginal effect of high consumer effort in reducing the accident probability is lower for a high-safety firm. To make the ideas more concrete, consider the SUV market where the SUV Volvo XC60 was among the top safety picks for 2014 and has a superior rating from the Insurance Institute for Highway Safety and Consumer Reports, while the Honda Pilot has a lower rating. Substitution between product safety and consumer effort implies that increased consumer care would have a lower effect on reducing the accident probability for the Volvo XC60 as compared to the Honda Pilot. Such a relationship is relevant for categories such as automobiles or appliances.

We require that $\theta_i \geq \frac{1}{2}$, which ensures that the probability of accident is bounded below one. If the consumer uses the product with care and an accident occurs, the court will require the firm to make a transfer L_f to the consumer using the strict liability rule. The assignment of liability when the consumer is negligent has been a topic of debate in the law of torts (see Glannon 2010). We adopt and model the most commonly used liability assignment rule in the United States called the "law of comparative negligence."¹⁰ When using the law of comparative negligence, the firm's liability for the accident is proportionally reduced by the court to reflect the negligence on the

part of the consumer in causing the accident.¹¹ Recall that the probability of accident when consumers use the product with care is $1 - \theta_i$ and increases to $(1 - \theta_i) \cdot (1 + \varepsilon)$ when consumers use the product negligently. The court attributes the increase in the probability of accident to the consumer. Therefore, the court determines the liability of the firm for an accident when the consumer uses the product negligently using the law of comparative negligence at $(1/(1 + \varepsilon))L_f$.

The timing of the game is the same as before except that now the consumer decides between using the product negligently or with care after product purchase. Suppose the consumers were to believe that the firm did not seek certification and set a price p_{NC} . If a consumer buys the product, she will have to decide whether or not to put out the effort e_h and use the product with care. The expected utility of the consumer from expending the effort is

$$U_h = v - p_{NC} - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)](L - L_f) - \kappa.$$

And the expected utility of the consumer from negligent use is given by

$$U_l = v - p_{NC} - [\alpha(1 - \theta_h)(1 + \varepsilon) + (1 - \alpha)(1 - \theta_l)(1 + \varepsilon)] \left(L - \frac{L_f}{1 + \varepsilon} \right).$$

In a PBE, consumer beliefs should end up being consistent. The consumer, given the belief that the firm did not seek certification, puts out effort e_h if $\varepsilon > \tilde{\varepsilon}$ and is negligent if $\varepsilon \leq \tilde{\varepsilon}$, where $\tilde{\varepsilon}$ is defined as

$$\tilde{\varepsilon} \equiv \frac{\kappa}{L[\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]}.$$

In like manner, suppose consumers believed that the firm chose to seek certification: If it gets successfully classified as type θ_h (i.e., gets the seal), the consumer chooses e_h if $\varepsilon > \tilde{\varepsilon}_S$ and e_l if $\varepsilon \leq \tilde{\varepsilon}_S$; whereas if the firm was unsuccessful and gets classified as type θ_l (i.e., does not get the seal), the consumer chooses e_h if $\varepsilon > \tilde{\varepsilon}_{NS}$ and e_l if $\varepsilon \leq \tilde{\varepsilon}_{NS}$. By comparing the consumer's utilities upon choosing effort e_h and e_l in each case, we get the expressions for $\tilde{\varepsilon}_S$ and $\tilde{\varepsilon}_{NS}$ as

$$\tilde{\varepsilon}_S \equiv \frac{\kappa[\alpha\rho + (1 - \alpha)(1 - \rho)]}{L[\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]},$$

$$\tilde{\varepsilon}_{NS} \equiv \frac{\kappa[\alpha(1 - \rho) + (1 - \alpha)\rho]}{L[\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]}.$$

We can see that $\alpha\rho/(\alpha\rho + (1 - \alpha)(1 - \rho)) > \alpha > \alpha(1 - \rho)/(\alpha(1 - \rho) + (1 - \alpha)\rho)$, and so the consumers' beliefs are the highest when the firm seeks certification and the product is safety certified, and the lowest when it is denied certification. As a consequence, we get the following important relationship:

$$\tilde{\varepsilon}_{NS} < \tilde{\varepsilon} < \tilde{\varepsilon}_S. \quad (1)$$

This inequality helps us to understand how the effort choice of the consumer changes with the effectiveness of her effort. If the effort is not very effective in reducing the likelihood of accident ($\varepsilon \leq \tilde{\varepsilon}_{NS}$), the firm’s certification decision or the outcome of certification will obviously have no effect on the level of care exercised by the consumers. Consumers will use the product negligently regardless of firm certification. At the other extreme, if the consumers’ effort plays a big role in making accidents less likely ($\varepsilon > \tilde{\varepsilon}_S$), they will find it optimal to put out effort and use the product with care regardless of the firm’s certification decision or the outcome of certification. Thus, it is only in the intermediate range of effectiveness of consumers’ effort that consumers’ equilibrium choice of effort is related to their beliefs about the firm’s certification decision and the outcome of certification. The following proposition describes this relationship and an important insight of this section.

Proposition 2. For range $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S$, and in the case where product safety and consumer effort are substitutes:

1. When consumers observe a positive certification seal, they will exert low effort and use the product negligently.
2. When consumers do not observe a certification seal,
 - (a) they will always exert high effort if their equilibrium belief is that the firm had decided to seek certification but was denied positive certification;
 - (b) they will exert low effort when $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}$, but switch to exerting high effort when $\tilde{\varepsilon} < \varepsilon \leq \tilde{\varepsilon}_S$, if their equilibrium belief is that the firm had decided to not seek certification.

The results are summarized in Table 1. Suppose that the firm decided to seek certification and was successful in receiving a positive certification. Consumers in this case can observe the certification seal and condition their actions accordingly. The first part of the proposition shows that consumers respond to a positive certification outcome by choosing not to exert effort for the entire range of effort effectiveness. This leads to the interesting point that the substitutability of the product’s inherent safety and consumer effort leads consumers to be negligent when they know that the product has been granted positive certification.

When no certification seal is observed, then the equilibrium beliefs of consumers about the firm’s certification decision matter for whether they will exert care

or be negligent in product usage. Consider the case where consumers believe that the firm chose to seek certification but was unsuccessful. In this case, consumer beliefs about the firm being the one with high safety (θ_h) are the most pessimistic. Consequently, conditional on purchase, they respond by choosing to put out costly effort in using the product with care.

In contrast, suppose that the consumers’ equilibrium belief was that the firm had decided not to seek certification at all. Now, the effectiveness of the effort in reducing the accident probability matters for the consumers’ effort choices. When the effectiveness is small and $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}$, consumers use the product negligently. But as the effectiveness increases and $\tilde{\varepsilon} < \varepsilon \leq \tilde{\varepsilon}_S$, consumers are motivated to put out effort. Why might this be the case? When the firm is believed to have eschewed certification, consumer beliefs about the firm being a high-safety type are not too pessimistic. So when the marginal productivity of her effort is small, the consumer strategically decides not to exert the costly effort that might not matter as much. It is only when the effectiveness of the effort is substantially large that the consumer finds it worthwhile to incur the effort cost of increasing safety. Thus, the belief about the firm’s decision to refrain from certification can have differing effects on equilibrium consumer behavior depending on the nature of consumer moral hazard: When consumer effort is less effective, no certification induces consumers to be negligent; but when the effort is sufficiently effective, no certification actually encourages consumers to be careful.

Table 1 provides an alternative way to understand the manner in which consumer moral hazard interacts with the certification strategies. As we go down the columns of the table, consumer beliefs about the firm being of high safety becomes progressively optimistic. Consumers respond to this and change their optimal effort choice from using the product with care to using the product negligently as their beliefs about product safety become more positive. This finding is reminiscent of the Peltzman effect (Peltzman 1975), which is the idea that individuals would adjust their behavior in response to the perceived level of risk and become less careful if they perceived that an product/activity was safer and, conversely, more careful if the product was perceived to be more risky. This idea has been also called the “risk compensation” phenomenon. Peltzman’s point was that safety interventions such as seat belts would end up having less effect on overall level of accidents because drivers would adjust and indulge in more risky driving behavior. This logic has been debated, and existing research has argued that while the effect is sensible in theory, it is not empirically significant (see Levitt and Porter 2001, Levitt 2006). Our analysis provides a perspective on this debate, which is predicated on the certification decisions of firms: Firm

Table 1. Consumer’s Effort Corresponding to Different Firm Strategies

Firm’s certification strategy/Outcome	Consumer’s effort choice	
	$\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}$	$\tilde{\varepsilon} < \varepsilon \leq \tilde{\varepsilon}_S$
Seek/Denied	e_h	e_h
Not seek	e_l	e_h
Seek/Granted	e_l	e_l

certification strategies can rationally make consumers behave as if they were indulging in the Peltzman effect-like behavior. In other words, consumers might switch from being careful in the use of the product to being negligent if their beliefs about the inherent product safety becomes more optimistic because of the firm's certification strategy and outcomes. When a firm goes for certification and is successful in getting a seal, it assures consumers that accident probabilities will likely be small even when they do not put out effort.

We next examine how the firm's certification decision affects the overall likelihood of accidents. As expected if $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}$, certification induces a lower likelihood of accident. This happens because certification creates the possibility that consumers use the product with care. It is, however, interesting to note that if $\tilde{\varepsilon} < \varepsilon \leq \tilde{\varepsilon}_S$, certification can actually make accidents more likely. Once again, consumers' choice of effort in response to their ex post beliefs about firm type drives this result. Consumers in this range of effort effectiveness use the product with care if the firm does not seek certification or is denied certification. However, if the firm is granted certification, consumers optimally choose not to put out effort and use the product negligently. Thus, seeking certification creates the possibility of negligent product use and makes accidents more likely as a result.

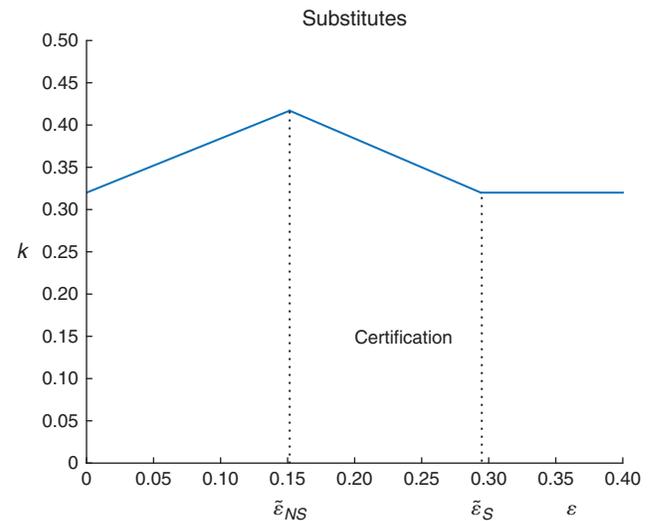
We now analyze the certification equilibrium with consumer moral hazard. The equilibrium conditions and the proof are presented in the appendix. The conditions under which the certification equilibrium exists are graphically presented in Figure 3. An examination of the equilibrium conditions and their comparison with those for the case without consumer moral hazard (presented in Proposition 1) reveal the following results:

Proposition 3. *If safety and effort are substitutes, the firm's incentive to seek voluntary safety certification*

1. *is higher compared to the case where there is no consumer moral hazard;*
2. *changes nonmonotonically with the effectiveness of the consumers' effort ε ; the incentive increases with ε if ε is small ($\varepsilon \leq \tilde{\varepsilon}_{NS}$), decreases with ε if it is in the intermediate range ($\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S$), and remains constant if ε is large enough ($\varepsilon > \tilde{\varepsilon}_S$).*

Consumer moral hazard increases the firm's incentives to seek safety certification. The intuition runs as follows: As in the case without consumer moral hazard, the inability of the consumer, in absence of a safety seal on the product, to distinguish between whether the firm was denied certification or one that did not seek certification in the first place creates incentives for product safety certification; but consumer moral hazard creates additional incentives if product safety and consumer effort are substitutes in reducing accident

Figure 3. (Color online) Firm's Incentives to Seek Product Safety Certification with Effectiveness of Consumers' Effort



Note. Parameter values are $\rho = 0.9$, $\theta_h = 0.7$, $\theta_l = 0.3$, $L_c = 2$, $L_f = 2$, $\kappa = 0.4$, $\alpha = 0.5$.

probabilities. Since safety and effort are substitutes, the effect of using the product negligently on the accident probability is largest if the firm is denied certification. Certification is seen as beneficial by consumers because they do not expect a large increase in the probability of accident if they use a safety-certified product negligently. As a result, the presence of consumer moral hazard makes certification more attractive for the firm if product safety and effort are substitutes.

Consistent with the above, voluntary certification is commonly observed in product categories where safety and effort are likely to be substitutes. For example, the American National Standards Institute has established voluntary safety standards for product categories such as home appliances, lawn mowers, etc., while UL (www.UL.com) is popular as a certification agency among manufacturers of electrical appliances, furniture, toys, and other consumer products. In fact, in the automobile industry, firms even subject themselves to voluntary public tests. As an example, the 2011 Volvo S60 came equipped with an automatic braking system that activated brakes if the driver failed to react in time to an object in front of the car. The automatic braking system and driver vigilance can be seen as substitutes in reducing the accident probability, and this is consistent with Volvo's motivation to voluntarily conduct public safety tests.

An interesting point that emerges from the analysis is a nonmonotonic effect of the effectiveness ε of the consumer's effort on the firm's incentives to seek safety certification. The firm's incentive to seek certification first increases, then decreases, and finally stays constant as ε increases. This result is driven by the changes in the consumers' optimal effort with increase in ε .

If effort is not very effective in reducing the accident probability ($\varepsilon \leq \tilde{\varepsilon}_{NS}$), consumers use the product negligently even when using a noncertified product. If effort becomes more effective consumers experience a larger reduction in the probability of accident when using the product with care compared to when using it negligently. Since safety and effort are substitutes, the effect of increase in ε on the probability of accident is larger when the firm is believed to be of lower safety; that is, when the firm is denied certification. Consumers expect a relatively smaller increase in the probability of accident when using a safety-certified product negligently compared to when using a noncertified product negligently. Consumers' willingness to pay for the product, and therefore the price set by the firm, drops with increase in ε , but it drops more for the noncertified product. The incentive for certification increases with increase in the effectiveness of effort, even as the equilibrium profits become lower, since profits upon deviation to not seeking certification reduces at a faster rate.

In the intermediate range of the effort effectiveness ($\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S$) consumers use the safety-certified product negligently but use the noncertified product with care. Since consumers use the noncertified product with care and accidents happen only due to inherent safety problems, an increase in ε has no direct effect on the probability of accidents in the case of noncertified product. Now, consider a safety-certified product: In this case, an increase in ε causes a larger increase in the probability of accident if consumers use the product negligently compared to using it with care. Therefore, the willingness to pay for the safety-certified product drops with the increase in ε , and so the firm sets a lower price for the safety-certified product. The equilibrium profits become smaller but the profits for deviation to not seeking certification remain unchanged. As a result, the incentive for certification reduces. If consumers' effort is so effective ($\varepsilon > \tilde{\varepsilon}_S$) that they use the product with care regardless of firm's certification decision or outcome of certification, then the firm's incentives for certification do not depend on the effectiveness of effort. This is because in this range of effort effectiveness, consumers use the product with care and the accidents happen only due to firm-related safety problems.

It is also interesting to note that the cost of consumer's effort κ increases the possibility of certification, when $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S$. In this range of ε , the certification decision of the firm changes the consumer's strategy as compared to if the firm did not seek certification. When consumer effort costs are higher, the firm is even more motivated to affect consumer behavior by adopting the certification decision. Finally, the presence of the consumer moral hazard also shrinks the parameter space over which the firm does

not seek certification in equilibrium. The intuition is similar to the certification equilibrium case described above.

3.2. The Complements Case

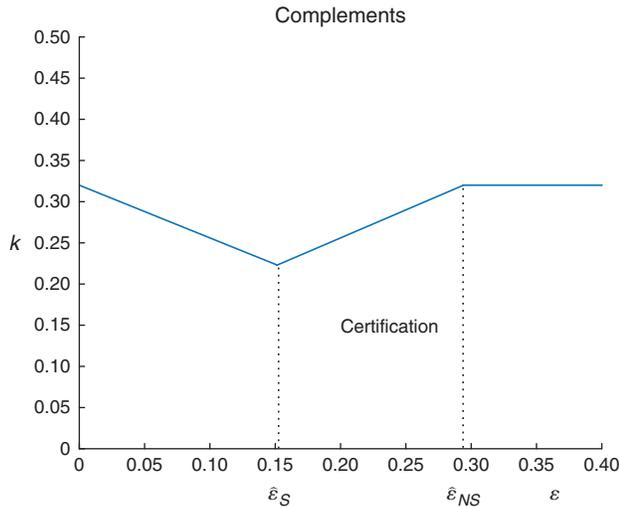
We now consider markets where consumer effort and product safety are complements. Consider products such as snow chains, fire extinguishers, and pharmaceutical drugs whose primary function itself is to provide safety/remedy. The safety characteristics of these products and the consumer effort in properly using them can be seen as complements. Specifically, the marginal effect of the high consumer effort e_h in reducing the accident probability is higher for a high-safety product.

Suppose, as in the previous section, the probability of accident when consumer puts out effort e_h is $1 - \theta_l$, but the probability of accident if the consumer puts effort e_l is represented by $1 - \theta_l + \theta_l \varepsilon$. As in the substitutes case, the parameter ε is the effectiveness of the consumer's effort and $0 < \varepsilon \leq 1$. Note that the formulation implies that the marginal reduction in the accident probability from increased effort is higher for products with higher safety. Also, the law of comparative negligence, as discussed in Section 3.1, implies that if the consumer uses the product negligently the liability of the firm for an accident can be written as $((1 - \theta_l)/(1 - \theta_l + \theta_l \varepsilon))L_f$.

We can now define thresholds $\hat{\varepsilon}_S$, $\hat{\varepsilon}$, and $\hat{\varepsilon}_{NS}$ such that the consumers use the product negligently for $\varepsilon \leq \hat{\varepsilon}_S$ if they believe the product to be safety certified, for $\varepsilon \leq \hat{\varepsilon}$ if they believe the firm did not seek certification, and for $\varepsilon \leq \hat{\varepsilon}_{NS}$ if they believe the firm was denied certification. Consumers use the product with care if ε is higher than thresholds $\hat{\varepsilon}_S$, $\hat{\varepsilon}$, and $\hat{\varepsilon}_{NS}$ for the respective beliefs. Since safety and effort are complements and consumers believe the safety-certified product to be of higher expected safety, they are most inclined to use the safety-certified product with care. The threshold $\hat{\varepsilon}_S$ is therefore the smallest of the three. Note that in the case when safety and effort were substitutes, the corresponding threshold $\tilde{\varepsilon}_S$ was the largest of the three since consumers were least inclined to use the safety certified product with care. Coming back to the complements case, since the consumers beliefs about the firm safety are intermediate when the firm does not seek certification and lowest when firm is denied certification, we have $\hat{\varepsilon}_S < \hat{\varepsilon} < \hat{\varepsilon}_{NS}$.

We can now compare consumers' choice of effort depending on their beliefs about firms certification strategy in different regions of ε . Consumers use the product negligently regardless of the firm's certification decision or the outcome of certification if $\varepsilon \leq \hat{\varepsilon}_S$; they use the product with care only when using a

Figure 4. (Color online) Firm's Incentives to Seek Product Safety Certification with Effectiveness of Consumers' Effort



Note. Parameter values are $\rho = 0.9$, $\theta_h = 0.7$, $\theta_l = 0.3$, $L_c = 2$, $L_f = 2$, $\kappa = 0.4$, $\alpha = 0.5$.

safety-certified product if $\hat{\varepsilon}_S < \varepsilon \leq \hat{\varepsilon}$; they use the product negligently only when using a product that was denied certification if $\hat{\varepsilon} < \varepsilon \leq \hat{\varepsilon}_{NS}$; and they use the product with care regardless of firm's certification decision or outcome of certification if $\varepsilon > \hat{\varepsilon}_{NS}$.

The expressions for $\hat{\varepsilon}_S$, $\hat{\varepsilon}$, and $\hat{\varepsilon}_{NS}$ can be derived in a manner similar to Section 3.1 and are as follows:

$$\hat{\varepsilon}_S \equiv \frac{\kappa[\alpha\rho + (1-\alpha)(1-\rho)]}{L[\alpha\rho\theta_h + (1-\alpha)(1-\rho)\theta_l]},$$

$$\hat{\varepsilon} \equiv \frac{\kappa}{L[\alpha\theta_h + (1-\alpha)\theta_l]},$$

$$\hat{\varepsilon}_{NS} \equiv \frac{\kappa[\alpha(1-\rho) + (1-\alpha)\rho]}{L[\alpha(1-\rho)\theta_h + (1-\alpha)\rho\theta_l]}.$$

As in the substitutes case, the consumers' choice of effort depends on the firm's certification decision or the outcome of certification only when the effectiveness of consumers' effort is in the intermediate range $\hat{\varepsilon}_S < \varepsilon \leq \hat{\varepsilon}_{NS}$. However, what is interesting is that the consumers' response to a more favorable belief about product safety is opposite of the Peltzman effect prediction. When safety and effort are complements, consumers actually become more willing to use a product which they believe to be of higher safety with care. The conditions under which certification equilibrium exists are graphically presented in Figure 4. An examination of the equilibrium conditions and their comparison with those for the case without consumer moral hazard leads us to the following proposition.

Proposition 4. *If safety and effort are complements, the firm's incentive to seek voluntary safety certification*

1. *is lower compared to if there is no consumer moral hazard;*

2. *changes nonmonotonically with the effectiveness of the consumers' effort ε ; the incentive decreases with ε if ε is small ($\varepsilon \leq \hat{\varepsilon}_S$), increases with ε if it is in the intermediate range ($\hat{\varepsilon}_S < \varepsilon \leq \hat{\varepsilon}_{NS}$), and remains constant if ε is large enough ($\varepsilon > \hat{\varepsilon}_{NS}$).*

Comparing Proposition 4 to Proposition 3 leads to one of the key points of the paper. In contrast to the substitutes case, here the presence of consumer moral hazard results in the firm seeking certification over a smaller set of conditions. In other words, unlike in the substitutes case, consumer moral hazard dampens firm certification incentives. With complementarity, consumers are more willing to use the product with care if they buy a safety-certified product as compared to a noncertified product. Because safety and effort are complements, the effect of negligent product use on the probability of accident is the lowest when the firm is denied certification. Certification is not seen as beneficial by consumers because they expect a large increase in the accident probability if they use a safety-certified product negligently. This, in turn, reduces the firm's incentives to seek certification. Complementarity expands the region of parameter space in which not seeking certification is an equilibrium.

The above result is consistent with the observation that voluntary certifications are not common in the pharmaceutical industry. To the extent that FDA approvals leave some uncertainty about the safety performance of many drugs, there should be a market for third-party voluntary certifications that can resolve that uncertainty. However, voluntary certifications are not at all observed in this industry. One reason could be that the patient compliance effort and drug safety may be complements which reduce certification incentives. It is also of interest to note that of the hundreds of fire extinguishers on Amazon.com, only three are UL listed.¹² We posit that the low incidence of firms seeking voluntary certifications for fire extinguishers may potentially be due to the complementarity of its inherent safety and consumer effort in its maintenance.

As in the case in which safety and effort are substitutes, we observe a nonmonotonic effect of the effectiveness of effort on the firm's incentive to seek certification; but what is interesting is that the nature of the nonmonotonicity is opposite. Unlike in the substitutes case, the firm's incentive to seek certification first decreases, then increases, and finally stays constant as the effectiveness of consumer effort increases. If the consumers' effort is not very effective ($\varepsilon \leq \hat{\varepsilon}_S$), they use the product negligently. An increase in the effectiveness of effort makes the negligent product use less desirable to consumers since they experience a larger increase in the probability of accident if they use the product negligently instead of using it with care. However, since safety and effort are complements,

the increase in the probability of accident is larger if the product is believed to be of higher safety; that is, if the product is safety certified. Consumers' willingness to pay for safety-certified product drops more than that for the noncertified product. The equilibrium profits drop at a faster rate than the profits upon deviation to not seeking certification. As a result, the firm's incentives to seek certification reduce with increase in ε , if effort is not very effective. Interestingly, however, in the intermediate range of effort effectiveness ($\tilde{\varepsilon}_S < \varepsilon \leq \tilde{\varepsilon}_{NS}$), the firm's incentive to seek certification increases with the effectiveness of consumers' effort. In this range, consumers use a safety-certified product with care but a noncertified product negligently. An increase in the effectiveness of effort has no effect on the probability of accident for the certified product since consumers use the certified product with care and accidents happen only due to product-related safety problems. Now, consider the noncertified product: an increase in the effectiveness of effort makes the product less desirable to consumers since consumers experience a larger increase in the probability of accident. Therefore, the firm sets a lower price. The firm profits on deviation to not seeking certification become much smaller compared to equilibrium profits with increase in ε . As a result, the firm's incentive to seek certification increases with ε . If consumers' effort is highly effective $\varepsilon > \tilde{\varepsilon}_{NS}$, they use the product with care regardless of certification decision of the firm. Therefore, the firm's incentive to seek certification is not affected by the effectiveness of consumers' effort if effort is highly effective.

3.3. Welfare Implications

We now summarize the welfare implication of product safety certification. First, consider the basic model without consumer moral hazard. In the absence of safety certification, both the consumers and the firm believe the product to be of type θ_h with probability α . The welfare in the absence of certification can be found by adding consumer surplus and firm's profits, and is given by $W_{NC} = v - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L$. If the firm seeks certification, it is granted certification with probability $\alpha\rho + (1 - \alpha)(1 - \rho)$ and is denied certification with probability $\alpha(1 - \rho) + (1 - \alpha)\rho$. Consumers believe the product to be of type θ_h with probability $\alpha\rho/(\alpha\rho + (1 - \alpha)(1 - \rho))$ if they observe a safety-certified seal, and with probability $\alpha(1 - \rho)/(\alpha(1 - \rho) + (1 - \alpha)\rho)$ if they do not. Therefore, we get the welfare in the presence of certification as $W_C = v - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L - k$. Thus, in the basic model, certification results in a lower welfare. This is because certification does not make the product any safer. It only changes the consumers' beliefs about product safety. The expected probability of accident remains the same. Therefore, if the firm sells the product to the consumers

even when it is denied certification (i.e., there is no demand effect) and if true product safety is independent of the certification decision (i.e., product safety is exogenous), then costly certification reduces welfare.

Next, consider the model with consumer moral hazard, presented in Section 3.1 (the derivation is presented in the appendix). In this setup, certification can be welfare enhancing in the intermediate range of effectiveness ε of consumers' effort $\tilde{\varepsilon}_{NS} < \varepsilon < \tilde{\varepsilon}_S$. If ε is out of this range, consumers exert the same level of effort regardless of certification decision of the firm or the outcome of certification. However, in the intermediate range, certification changes the optimal effort choice of the consumer. In this range, welfare first increases (if $\tilde{\varepsilon}_{NS} < \varepsilon < \tilde{\varepsilon}$) and then decreases (if $\tilde{\varepsilon} < \varepsilon < \tilde{\varepsilon}_S$) with increase in ε . This is because certification induces careful product use if $\tilde{\varepsilon}_{NS} < \varepsilon < \tilde{\varepsilon}$, whereas it induces negligent product use if $\tilde{\varepsilon} < \varepsilon < \tilde{\varepsilon}_S$. Since an increase in ε makes consumers more willing to use the product with care, ex post consumer surplus increases with ε if $\tilde{\varepsilon}_{NS} < \varepsilon < \tilde{\varepsilon}$ and decreases with ε if $\tilde{\varepsilon} < \varepsilon < \tilde{\varepsilon}_S$. As a result, in the intermediate range of ε , the welfare first increases and then decreases with increase in ε . Therefore, certification can be welfare enhancing in the presence of consumer moral hazard. It is important to note that for certification to be welfare enhancing it must be the case that the consumer is motivated to change her optimal effort choice as a result of firm's certification decision. The result about higher welfare in the intermediate range of effort effectiveness holds in both the substitutes (Section 3.1) and the complements (Section 3.2) cases.

4. Extensions

In this section, we develop three extensions to the models presented above. The first allows the effort choice of the consumer to be continuous, the second investigates alternative product liability assignment rules, and the third presents the analysis in a setup in which the firm does not sell the product if it is denied certification but sells otherwise.

4.1. Continuous Effort

In the analysis presented so far, we assume that the consumer chooses between careful (e_h) and negligent (e_l) use of the product. In this extension, we allow effort (e) to be continuous. The cost of effort is $\frac{1}{2}\tau e^2$. The probability of accident is assumed $(1 - \theta_l)[1 + \varepsilon(1 - e)]$. This functional form captures the following assumptions: (i) The inherent product safety θ_l and consumer effort e are substitutes (i.e., the marginal effect of higher effort in reducing the accident probability is lower for the high-safety firm). (ii) If consumers use the product with care ($e = 1$), accidents happen with probability $1 - \theta_l$. The liability of the firm for an accident using the law of comparative negligence is $L_f/(1 + \varepsilon(1 - e))$.

Table 2. Consumer’s Effort Corresponding to Different Firm Strategies

Certification strategy/Outcome	Consumer’s effort choice	
	$\tilde{\epsilon}_{NS} < \epsilon \leq \tilde{\epsilon}$	$\tilde{\epsilon} < \epsilon \leq \tilde{\epsilon}_S$
Seek/Denied	1	1
Not seek	$\frac{[\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L\epsilon}{\tau}$	1
Seek/Granted	$\frac{[\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]L\epsilon}{[\alpha\rho + (1 - \alpha)(1 - \rho)]\tau}$	$\frac{[\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]L\epsilon}{[\alpha\rho + (1 - \alpha)(1 - \rho)]\tau}$

Similar to the model presented in Section 3.1, consumers use the product with care ($e = 1$) for $\epsilon > \tilde{\epsilon}$ if they believe the firm did not seek certification, for $\epsilon > \tilde{\epsilon}_S$ if they believe the firm was granted certification, and for $\epsilon > \tilde{\epsilon}_{NS}$ if they believe the firm was denied certification. Otherwise, they use the product negligently ($e < 1$). A comparison of consumer’s expected utility in the case of careful and negligent product use gives

$$\tilde{\epsilon}_S \equiv \frac{\tau[\alpha\rho + (1 - \alpha)(1 - \rho)]}{L[\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]'}$$

$$\tilde{\epsilon} \equiv \frac{\tau}{L[\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]'}$$

$$\tilde{\epsilon}_{NS} \equiv \frac{\tau[\alpha(1 - \rho) + (1 - \alpha)\rho]}{L[\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]'}$$

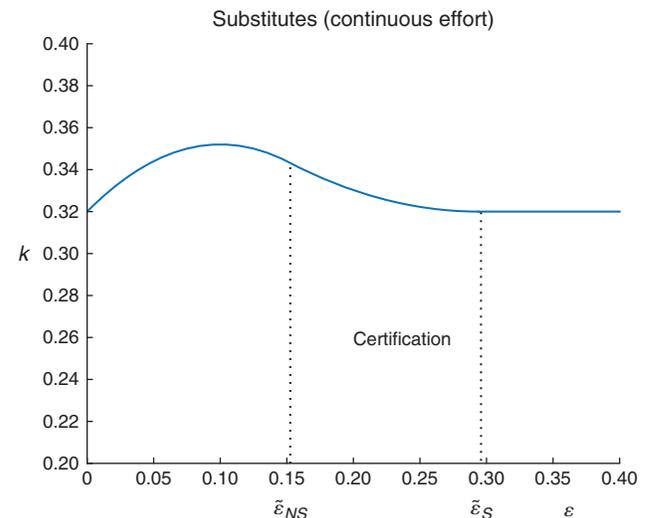
Since the consumers’ beliefs about the firm type are highest when the firm is granted certification and are lowest when the firm is denied certification, we get $\tilde{\epsilon}_{NS} < \tilde{\epsilon} < \tilde{\epsilon}_S$. Therefore, consumers respond to different firm strategies in the same manner as presented in Proposition 2. We present these results in Table 2 below. Note the consumer responds to higher beliefs about the firm safety by reducing the effort while using the product.

Next, we examine certification equilibrium and compare results to those presented in Proposition 3. The existence conditions for the certification equilibrium are graphically presented in Figure 5. The formal statements and proofs are in the appendix. A comparison of the conditions under which the firm seeks certification in equilibrium reveals that consumer moral hazard can lead to higher incentives for the firm to seek voluntary safety certification. We also discover a nonmonotonic effect of the effectiveness of consumers’ effort on the firm’s incentives to seek certification. The firm’s incentives to seek safety certification first increases, then decreases, and then remains constant with increase in the effectiveness ϵ of consumers’ effort. All of the results presented in Section 3.1 (the model with discrete effort levels) are robust to this extension. It is straightforward to show that the results presented in Section 3.2 also continue to hold if we consider effort continuous in the case where safety and effort are complements.

4.2. Alternative Product Liability Assignment Rules

In the analysis presented so far, we adopted the most widely used rule (i.e., “the law of comparative negligence”) to determine the firm’s liability in the case of an accident. In this section, we examine the other two forms of liability assignment rules that are prevalent in the United States: the strict liability and the contributory negligence. Under the strict liability rule, the firm is held accountable for damages to the same extent regardless of the level of care exercised by the consumer. Whereas under the contributory negligence rule, the firm is held liable only if the consumer has exercised the maximum level of care, i.e., has not contributed to the accident (see Glannon 2010 for a discussion). We implement strict liability in the setup of the main model by assuming that the firm’s liability is L_f regardless of the effort chosen by the consumer. Contributory negligence is implemented by assuming that firm’s liability is L_f if the consumer uses the product with care but is zero if the consumer is negligent. Both of these cases are derived in the appendix.

Figure 5. (Color online) Firm’s Incentives to Seek Product Safety Certification with Effectiveness of Consumers’ Effort



Note. Parameter values are $\rho = 0.9$, $\theta_h = 0.7$, $\theta_l = 0.3$, $L_c = 2$, $L_f = 2$, $\tau = 0.4$, $\alpha = 0.5$.

First, consider the strict liability rule: Consumers obviously become less likely to use the product with care since they get fully compensated even when they are negligent. As a result, all of the three thresholds $\tilde{\epsilon}_{NS}$, $\tilde{\epsilon}$, and $\tilde{\epsilon}_S$ for the substitutes case move to the right. However, the relationship $\tilde{\epsilon}_{NS} < \tilde{\epsilon} < \tilde{\epsilon}_S$, and the entire discussion pertaining to the risk compensation phenomenon following Proposition 2, will continue to hold. As in the main model, additional incentives for certification are created under moral hazard, and the firm's incentives to seek certification first increases then decreases and then stay unchanged with an increase in the effectiveness of consumers' effort. Similarly, if safety and effort are complements, all of the three thresholds $\hat{\epsilon}_{NS}$, $\hat{\epsilon}$, and $\hat{\epsilon}_S$ become higher since consumers become more willing to use the product negligently, but the relationship $\hat{\epsilon}_S < \hat{\epsilon} < \hat{\epsilon}_{NS}$ continues to hold. The result about the nonmonotonic effect of the effectiveness of consumers' effort on the firm's incentive to seek certification is also robust to the assumption of strict liability rule. The intuition for these results is exactly the same as for the case of comparative negligence.

Next, suppose that the court follows the law of contributory negligence when deciding a firm's liability in the case of an accident. In this case, consumers become more likely to use the product with care since their expected loss in the case of an accident is higher. Therefore, all of the thresholds ($\tilde{\epsilon}_{NS}$, $\tilde{\epsilon}$, and $\tilde{\epsilon}_S$ for the substitutes case, and $\hat{\epsilon}_{NS}$, $\hat{\epsilon}$, and $\hat{\epsilon}_S$ for the complements case) become smaller. However, the risk compensation result, as well as the nonmonotonic effect of the effectiveness of the consumers' effort on the firm's incentives to seek certification, continue to hold in this setup as well.

4.3. When the Certification Decision Can Be Inferred from Prices

In the analysis presented so far, we assumed that the firm is willing to sell the product to consumers when certification is denied. The rationale for this assumption was to rule out the demand-based explanations for the safety certification and focus on the more interesting incentives-based rationales for certification. One implication of the assumption was that if a firm deviated from the certification equilibrium, consumers believed that the firm was denied certification as they would not be able to distinguish between the denial of certification and no certification. In this extension, we consider the case where the product valuation v is such that the firm does not find it optimal to sell to consumers at some price p_{NS} along the equilibrium path even if consumers upon observing price p_{NS} were to believe that the firm deviated to not seeking certification. However, the firm is willing to sell at the same

price if it deviates to not seeking certification. Therefore, if the consumers observe that the firm is willing to sell the product at price p_{NS} , they rationally infer that the firm must have deviated to not seeking certification. Thus, the firm sets price p_{NS} when it deviates to not seeking certification and would like to sell at that price.

As in the basic model, incentive for certification is created because the firm sets price at p_{NS} even when it deviates to not seeking certification. In this setup, additional incentives for certification are created because certification gives the firm the option of not selling the product when consumers' beliefs about the firm type become unfavorable as a result of denied certification. In the model with consumer moral hazard, if safety and effort are substitutes, additional incentives for certification are created, similar to Section 3.1. The result pertaining to the nonmonotonic effect of the effectiveness of consumers' effort on the firm's incentive to seek safety certification is robust to this extension. The firm's incentive to seek certification first increases, then decreases, and then remains unchanged with an increase in the effectiveness of the consumers' effort. It is, however, interesting to note that if safety and effort are complements, the incentives for certification may increase in this case with an increase in the effectiveness of effort. This happens because the demand effect dominates the effect of consumer moral hazard if the likelihood that the firm is denied certification is large enough. Although in the substitutes case the effect of consumer moral hazard acts in the same direction as the demand effect, in the complements case the two effects act in the opposite direction. If safety and effort are complements, the demand effect increases the incentives for certification, whereas moral hazard reduces it.

5. Conclusion

Almost all of the consumer products that are legally sold meet a set of minimum safety standards specified by regulatory bodies. Against this backdrop, the wide prevalence of voluntary safety certifications for which the safety standards are usually much more exacting is an interesting phenomenon. Automobile manufacturers seek European New Car Assessment Programme (Euro (NCAP)) certification, toy manufacturers seek American National Standards Institute or ASTM International certification, and bike helmet manufacturers may seek Snell Certification. This paper examines the incentives of firms to seek costly safety certification and analyzes the effect of consumer moral hazard and the informational characteristics of the market on equilibrium safety certification.

There exist incentives for a firm to seek safety certification even if the firm and the consumers have

same beliefs about the product's safety. Many consumer products fall in this category due to U.S. laws that require firms to disclose all safety-related issues to consumers. The result emerges from the fact that neither the firm nor the certification agencies disclose denied certifications, so consumers learn about the certification decisions only when the outcome is positive.

The important result of this paper is that consumer moral hazard increases the incidence of certification when safety and consumer effort are substitutes in deciding the probability of accident-free use, but it decreases the incidence when they are complements. This is because using a product negligently in the substitutes case is more painful for the consumer when buying from a firm which is denied certification, but in the case of complements, using the product negligently is more painful when certification is successful and the product is certified as a high-safety product. Our paper also identifies an interesting nonmonotonic relationship between the effectiveness of consumers' effort and the firm's incentives to seek certification.

Certification can be welfare enhancing in the presence of consumer moral hazard regardless of whether safety and effort are substitutes or complements. This increase in welfare originates from the change in the consumers' optimal choice of effort, as certification provides her better information about product safety. However, if certification has no effect on consumers' choice of effort or if there is no consumer moral hazard, certification leads to lower welfare. This result has policy implications for voluntary certification agencies.

Promoting product safety is an important policy and consumer-welfare imperative. Our paper contributes by highlighting the role of voluntary certification in allowing firms to alleviate safety concerns. There are some questions that may be potentially useful to consider in future work in this area. The growth of the Internet and social media provides another channel for consumers to learn about safety, i.e., the experience and the reports of other consumers. In this context, there are incentives for online intermediaries to aggregate consumer reviews and safety ratings. Understanding the role of this channel and how it would affect firm strategies could be an interesting research issue. It would also be useful to explore the signaling incentives for product safety as a parallel to the literature on the signaling of quality or demand potential (e.g., Milgrom and Roberts 1986, Gal-Or 1989, Desai and Srinivasan 1995, Padmanabhan et al. 1997, Iyer and Kuksov 2010). There exists work on signaling safety through prices (Daughety and Reinganum 2008), but an interesting problem would be to analyze the role of certification in safety signaling under consumer moral hazard. Additionally, it may be of interest to explore the optimal liability assignment mechanism in the presence of product safety certification. Finally, another

important area would be to investigate competition between firms on the safety dimension and the conditions under which competition would promote greater product-safety investments.

Acknowledgments

The authors thank the editor, the associate editor, and reviewers for thoughtful comments. They also thank Ned Augenblick, Ying-Ju Chen, Pedro Gardete, Shachar Kariv, Zsolt Katona, J. Miguel Villas-Boas, and seminar participants at the University of Washington, Seattle, for comments. The authors are listed alphabetically.

Appendix

Proof of Proposition 1

Certification Equilibrium. Let us first consider the candidate equilibrium in which the firm seeks certification ($c = C$) and in which the consumers' beliefs about the firm's certification are consistent with the firm's decision ($\lambda = 1$). If the certification outcome happens to be positive then the firm sets price p_S but if the outcome happens to be negative and the certification is denied then the firm sets an associated price of p_{NS} . Given the firm's pricing strategies the consumers will use Bayes's rule to form beliefs $\mu(\lambda, o, p)$ about the firm's type which can be specified as

$$\mu(\lambda, o, p) = \begin{cases} \frac{\rho\alpha}{\rho\alpha + (1-\rho)(1-\alpha)} & \text{if } \lambda = 1, o = S, p = p_S, \\ \frac{\alpha(1-\rho)}{\alpha(1-\rho) + (1-\alpha)\rho} & \text{if } \lambda = 1, o = NS, p = p_{NS}. \end{cases}$$

Given these beliefs the consumers' expected utility upon observing firm's pricing strategies is

$$U(\mu(\lambda, o, p), p) = v - p - [\mu(\lambda, o, p)(1 - \theta_h) + (1 - \mu(\lambda, o, p))(1 - \theta_l)](L - L_f).$$

Note that the firm's optimal pricing strategies will involve prices p_S and p_{NS} that extract all of the consumer surplus. Therefore, the firm's pricing strategies which are consistent with consumer beliefs can be written as

$$p_S = v - \left(\frac{\rho\alpha(1 - \theta_h) + (1 - \rho)(1 - \alpha)(1 - \theta_l)}{\rho\alpha + (1 - \rho)(1 - \alpha)} \right) L_c,$$

$$p_{NS} = v - \left(\frac{\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)}{\alpha(1 - \rho) + (1 - \alpha)\rho} \right) L_c$$

If the firm seeks certification ($c = C$) and consumers indeed believe that the firm sought certification ($\lambda = 1$), the firm's profits can be written as

$$\pi^C = [\rho\alpha + (1 - \rho)(1 - \alpha)]p_S + [\alpha(1 - \rho) + (1 - \alpha)\rho]p_{NS} - k - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L_f.$$

However, for seeking certification to be an equilibrium strategy the firm profits given above must be higher than profits in the case of deviation to not seeking certification. Note the consumers do not observe certification decision of the firm. They infer the firm's certification decision from the firm's observed pricing strategy and the presence or absence of safety seal. Therefore, if the firm deviates to not seeking certification ($c = NC$), and therefore has no safety seal, but

continues to set the same price p_{NS} , consumers would continue to believe that the firm went for certification ($\lambda = 1$) but was denied certification ($o = NS$). But suppose the firm were to set some price $p' > p_{NS}$ upon deviation and consumers were to associate this price to the deviation ($\lambda = 0$) and be willing to buy. Then consumers would rationally know that even on the equilibrium path ($c = C$) when the firm is declined certification ($o = NS$), the firm will have incentive to set price at p' . Knowing this the consumer would not buy at any price $p' > p_{NS}$ in the absence of safety seal. Therefore, in the case of deviation to not seeking certification the firm can only set $p' = p_{NS}$. Therefore, the profits associated with a deviation to not seeking certification and setting price p_{NS} is given by

$$\pi^D = p_{NS} - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L_f.$$

Therefore, in a PBE the firm seeks certification if $\pi^C \geq \pi^D$ or

$$k \leq \frac{\alpha(1 - \alpha)(2\rho - 1)(\theta_h - \theta_l)L_c}{\alpha(1 - \rho) + (1 - \alpha)\rho}.$$

No Certification Equilibrium. Next we consider the candidate equilibrium in which the firm does not seek certification ($c = NC$) and the consumers believe that the firm did not seek certification ($\lambda = 0$). In this case the consumers upon not observing a safety seal will believe the firm to be of high type with probability α . Given this belief the firm's optimal strategy will be to set a price $p_{NC} = v - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L_c$ which extracts all of the consumer surplus. If the firm does not seek certification ($c = NC$) and if the consumers indeed believe that the firm did not seek certification ($\lambda = 0$), the firm's profits can be written as

$$\pi^{NC} = p_{NC} - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L_f.$$

To establish that the above strategies and beliefs constitute a PBE, we must show that the firm does not have any incentive to deviate and seek certification. Suppose the firm deviates to seeking certification ($c = C$) but is denied ($o = NS$) it should set price at p_{NC} as this is the highest price that can possibly be charged in the absence of seal given the consumers' equilibrium beliefs ($\lambda = 0$) that the firm did not seek certification. However, upon the firm's deviation if the consumers were to observe a seal then they will know with probability one that the firm has sought certification ($\lambda = 1$) and therefore will believe the firm to be of high type with probability $\alpha\rho/(\alpha\rho + (1 - \alpha)(1 - \rho))$. The firm will set the price p_S when it is granted certification. Therefore, we can write the firm's deviation profits as,

$$\pi^D = [\rho\alpha + (1 - \rho)(1 - \alpha)]p_S + [\alpha(1 - \rho) + (1 - \alpha)\rho]p_{NC} - k - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L_f.$$

In a PBE the firm will not seek certification if $\pi^{NC} \geq \pi^D$, which simplifies to

$$k \geq \alpha(1 - \alpha)(2\rho - 1)(\theta_h - \theta_l)L_c.$$

Mixed Strategy Equilibrium. Next consider a mixed strategy equilibrium in which the firm seeks certification with some probability σ , and the consumers' beliefs are consistent ($\lambda = \sigma$). The firm sets equilibrium prices p'_S and p'_{NS} with or without the certification seal respectively conditional on

consumer beliefs. The equilibrium consumer beliefs can be derived using Bayes's rule as

$$\mu(\lambda, o, p) = \begin{cases} \frac{\rho\alpha}{\rho\alpha + (1 - \rho)(1 - \alpha)} & \text{if } \lambda = \sigma, o = S, p = p'_S, \\ \frac{\alpha(1 - \rho)\sigma + \alpha(1 - \sigma)}{\alpha(1 - \rho)\sigma + \alpha(1 - \sigma) + (1 - \alpha)\rho\sigma + (1 - \alpha)(1 - \sigma)} & \\ \frac{\alpha(1 - \rho)\sigma + \alpha(1 - \sigma)}{\alpha(1 - \rho)\sigma + \alpha(1 - \sigma) + (1 - \alpha)\rho\sigma + (1 - \alpha)(1 - \sigma)} & \text{if } \lambda = \sigma, o = NS, p = p'_{NS}. \end{cases}$$

The firm must be indifferent between seeking and not seeking certification. Equating firm profits in the case of certification and no certification decision results in

$$k = [\rho\alpha + (1 - \rho)(1 - \alpha)](p'_S - p'_{NS}).$$

This equilibrium exists in the parameter space where both certification and no certification equilibria exist.

Proof of Proposition 2

We first show that if safety and effort are substitutes, then

$$\tilde{\varepsilon}_{NS} < \tilde{\varepsilon} < \tilde{\varepsilon}_S$$

or

$$\begin{aligned} & \frac{\kappa[\alpha(1 - \rho) + (1 - \alpha)\rho]}{L[\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]} \\ & < \frac{\kappa}{L[\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]} \\ & < \frac{\kappa[\alpha\rho + (1 - \alpha)(1 - \rho)]}{L[\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]} \end{aligned}$$

or

$$\begin{aligned} & \frac{\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)}{\alpha(1 - \rho) + (1 - \alpha)\rho} \\ & > \alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l) \\ & > \frac{\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)}{\alpha\rho + (1 - \alpha)(1 - \rho)}. \end{aligned}$$

The above expression holds given $\alpha(1 - \rho)/(\alpha(1 - \rho) + (1 - \alpha)\rho) < \alpha < \alpha\rho/(\alpha\rho + (1 - \alpha)(1 - \rho))$ (which holds $\forall \rho > \frac{1}{2}$).

1. Recall that by definition, if $\varepsilon \leq \tilde{\varepsilon}_S$, consumers exert low effort when using a safety-certified product. Since $\tilde{\varepsilon}_{NS} < \tilde{\varepsilon} < \tilde{\varepsilon}_S$, consumers exert low effort and use the product negligently for all $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S$.

2. When consumers do not observe a certification seal, it is either because the firm was denied certification or it did not seek certification in the first place. In a PBE, consumers' beliefs about firm's certification decision are correct. We first consider the case when the firm actually seeks certification but is denied a certification seal.

(a) If the firm is denied certification, consumers use the product with care for $\varepsilon > \tilde{\varepsilon}_{NS}$. Since $\tilde{\varepsilon}_{NS} < \tilde{\varepsilon} < \tilde{\varepsilon}_S$, consumers exert high effort for all $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S$.

(b) Now we consider the case in which consumers do not observe the certification seal because the firm does not seek certification in equilibrium. Consumers exert high effort only for $\varepsilon > \tilde{\varepsilon}$ and use the product negligently otherwise. Therefore, given $\tilde{\varepsilon}_{NS} < \tilde{\varepsilon} < \tilde{\varepsilon}_S$, consumers will exert low effort when $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}$ but switch to exerting high effort when $\tilde{\varepsilon} < \varepsilon \leq \tilde{\varepsilon}_S$ in equilibrium.

Equilibrium Derivation for the Substitutes Case

If product safety and consumer effort are substitutes, the equilibrium involves

1. the firm seeking certification if

$$k \leq \begin{cases} \frac{\alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)(L_c+\varepsilon L)}{\alpha(1-\rho)+(1-\alpha)\rho} & \text{if } \varepsilon \leq \tilde{\varepsilon}_{NS}, \\ \frac{\alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)L_c}{\alpha(1-\rho)+(1-\alpha)\rho} + K_s & \text{if } \tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S, \\ \frac{\alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)L_c}{\alpha(1-\rho)+(1-\alpha)\rho} & \text{if } \varepsilon > \tilde{\varepsilon}_S, \end{cases}$$

where $K_s \equiv \kappa(\alpha\rho + (1-\alpha)(1-\rho)) - \varepsilon L[\alpha\rho(1-\theta_h) + (1-\alpha)(1-\rho)(1-\theta_l)]$;

2. the firm not seeking certification if

$$k \geq \begin{cases} \alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)(L_c+\varepsilon L) & \text{if } \varepsilon \leq \tilde{\varepsilon}, \\ \alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)L_c + K_s & \text{if } \tilde{\varepsilon} < \varepsilon \leq \tilde{\varepsilon}_S, \\ \alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)L_c & \text{if } \varepsilon > \tilde{\varepsilon}_S; \end{cases}$$

3. the firm mixing between certification and no certification in the region of parameter space where both certification and no certification equilibria exist.

Certification Equilibrium. We first consider the candidate equilibrium in which the firm seeks certification. The conditions under which equilibria exist are derived for the different ranges of parameter ε .

(a) If $\varepsilon \leq \tilde{\varepsilon}_{NS}$: In this range of ε , the consumer takes the effort e_l regardless of the certification outcome. If the certification outcome happens to be positive ($o = S$), then the firm sets price p_S ; but if the outcome happens to be negative and certification is denied ($o = NS$), then the firm sets an associated price of p_{NS} . Given the firm’s pricing strategies, consumers will use Bayes’s rule to form beliefs $\mu(\lambda, o, p)$ about the firm’s type as described in the proof of Proposition 1. The firm sets prices p_S and p_{NS} optimally to extract all of the consumer surplus. Therefore, the firm’s pricing strategies, which are consistent with consumer beliefs, can be written as

$$p_S = v - \left[\frac{\alpha\rho(1-\theta_h) + (1-\alpha)(1-\rho)(1-\theta_l)}{\alpha\rho + (1-\alpha)(1-\rho)} \right] [(1+\varepsilon)L - L_f],$$

$$p_{NS} = v - \left[\frac{\alpha(1-\rho)(1-\theta_h) + (1-\alpha)\rho(1-\theta_l)}{\alpha(1-\rho) + (1-\alpha)\rho} \right] [(1+\varepsilon)L - L_f].$$

If the firm did seek certification ($c = C$) and consumers indeed believed so ($\lambda = 1$), then the firm’s profits can be written as

$$\pi_C = v - [\alpha(1-\theta_h) + (1-\alpha)(1-\theta_l)](1+\varepsilon)L - k.$$

Seeking certification will be an equilibrium strategy for the firm if the above profits are higher than if the firm were to deviate to not seeking certification. Recall that the consumers do not observe the certification decision of the firm and infer it from the firm’s observed pricing strategy and the presence or absence of the safety seal. Therefore, if the firm were to deviate to not seeking certification ($c = NC$) and continue to set the same price p_{NS} , consumers would continue to believe that the firm went for certification ($\lambda = 1$) but was denied ($o = NS$). But suppose the firm were to set some price

$p' > p_{NS}$ when it deviates to not seeking certification. Consumers, upon observing this price, would not change their beliefs about the firm type because if they were to do so, the firm would want to set this higher price on the equilibrium path when it is denied certification. Therefore, upon any deviation to not seeking certification, the firm can only set $p' = p_{NS}$. Therefore, the profits associated with a deviation to not seeking certification and setting price p_{NS} is given by

$$\pi_D = v - \left[\frac{\alpha(1-\rho)(1-\theta_h) + (1-\alpha)\rho(1-\theta_l)}{\alpha(1-\rho) + (1-\alpha)\rho} \right] [(1+\varepsilon)L - L_f] - [\alpha(1-\theta_h) + (1-\alpha)(1-\theta_l)]L_f.$$

Therefore, in a PBE the firm seeks certification if $\pi_C \geq \pi_D$, or

$$k \leq \frac{\alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)(L_c+\varepsilon L)}{\alpha(1-\rho)+(1-\alpha)\rho}.$$

(b) If $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S$: In this range of ε , the consumer takes effort e_l if the product is classified as type θ_h and takes effort e_h if the product is classified as type θ_l by the certification agency. The equilibrium prices and profits, as well as profits under deviation to no certification, can be derived as in part (a). A comparison of firm profits under equilibrium and under deviation to no certification gives the condition

$$k \leq \frac{\alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)L_c}{\alpha(1-\rho)+(1-\alpha)\rho} + K_s,$$

where

$$K_s \equiv \kappa(\alpha\rho + (1-\alpha)(1-\rho)) - \varepsilon L[\alpha\rho(1-\theta_h) + (1-\alpha)(1-\rho)(1-\theta_l)].$$

(c) If $\varepsilon > \tilde{\varepsilon}_S$: If ε is sufficiently large ($\varepsilon > \tilde{\varepsilon}_S$), consumers takes effort e_h regardless of the certification outcome. The prices and profits can be derived as in part (a). The existence condition for the certification equilibrium, which is obtained by comparing equilibrium profits to profits under deviation to no certification, can be written as

$$k \leq \frac{\alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)L_c}{\alpha(1-\rho)+(1-\alpha)\rho}.$$

No Certification Equilibrium. Next we consider the candidate equilibrium in which the firm does not seek certification. If a firm deviates to seeking certification, the consumers, upon observing the seal, would believe that the firm has gone for certification; but upon not observing the seal, the firm will be indistinguishable from one that did not seek certification. So consumers would still believe that the firm has chosen not to go for certification. They would, therefore, be willing to pay a higher price than if they could observe that the firm has actually been denied a seal. Using analysis which is similar to the proof of Proposition 1, a comparison of profits under equilibrium and the deviation profits reveals that the equilibrium exists if

$$k \geq \begin{cases} \alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)(L_c+\varepsilon L) & \text{if } \varepsilon < \tilde{\varepsilon}, \\ \alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)L_c + K_s & \text{if } \tilde{\varepsilon} < \varepsilon < \tilde{\varepsilon}_S, \\ \alpha(1-\alpha)(2\rho-1)(\theta_h-\theta_l)L_c & \text{if } \varepsilon > \tilde{\varepsilon}_S. \end{cases}$$

Mixed Strategy Equilibrium. Next, consider a mixed strategy equilibrium in which the firm seeks certification with some probability σ . The firm sets equilibrium prices p_S and p'_{NS} in the presence and absence of the certification seal, respectively, conditional on consumer beliefs. The equilibrium consumer beliefs can be derived using Bayes's rule as

$$\begin{aligned} \mu(\sigma, S, p_S) &= \frac{\alpha\rho}{\alpha\rho + (1-\alpha)(1-\rho)}, \\ \mu(\sigma, NS, p'_{NS}) &= \frac{\alpha\sigma(1-\rho) + \alpha(1-\sigma)}{\alpha\sigma(1-\rho) + \alpha(1-\sigma) + (1-\alpha)\rho\sigma + (1-\alpha)(1-\sigma)}. \end{aligned}$$

The firm must be indifferent between seeking and not seeking certification. Equating firm profits in the case of certification and no certification decision results in

$$k = [\rho\alpha + (1-\rho)(1-\alpha)](p_S - p'_{NS}).$$

It is straightforward to show that in the entire range of ε , the mixed strategy equilibrium exists in the same region where both certification and no certification equilibria exist.

Proof of Proposition 3

1. Follows directly from the comparison of the certification equilibrium conditions outlined in Proposition 1 and those described in the certification equilibrium analysis for substitutes case above.

2. If \bar{k}_s is the maximum cost for which the certification equilibrium exists, given safety and effort are substitutes

$$\frac{\partial \bar{k}_s}{\partial \varepsilon} = \begin{cases} \frac{\alpha(1-\alpha)(2\rho-1)(\theta_h - \theta_l)L}{\alpha(1-\rho) + (1-\alpha)\rho} > 0 & \text{if } \varepsilon \leq \tilde{\varepsilon}_{NS}, \\ -L[\alpha\rho(1-\theta_h) + (1-\alpha)(1-\rho)(1-\theta_l)] < 0 & \text{if } \tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S, \\ 0 & \text{if } \varepsilon > \tilde{\varepsilon}_S. \end{cases}$$

Equilibrium for the Complements Case

If product safety and consumer effort are complements, the equilibrium involves

1. the firm seeking certification if

$$k \leq \begin{cases} \frac{\alpha(1-\alpha)(2\rho-1)(\theta_h - \theta_l)(L_c - \varepsilon L)}{\alpha(1-\rho) + (1-\alpha)\rho} & \text{if } \varepsilon \leq \hat{\varepsilon}_S, \\ \frac{\alpha(1-\alpha)(2\rho-1)(\theta_h - \theta_l)L_c}{\alpha(1-\rho) + (1-\alpha)\rho} + K_c & \text{if } \hat{\varepsilon}_S < \varepsilon \leq \hat{\varepsilon}_{NS}, \\ \frac{\alpha(1-\alpha)(2\rho-1)(\theta_h - \theta_l)L_c}{\alpha(1-\rho) + (1-\alpha)\rho} & \text{if } \varepsilon > \hat{\varepsilon}_{NS}, \end{cases}$$

where $K_c \equiv (\alpha\rho + (1-\alpha)(1-\rho))[-\kappa + \varepsilon L([\alpha(1-\rho)\theta_h + (1-\alpha)\rho\theta_l]/(\alpha(1-\rho) + (1-\alpha)\rho))]$;

2. the firm not seeking certification if

$$k \geq \begin{cases} \alpha(1-\alpha)(2\rho-1)(\theta_h - \theta_l)(L_c - \varepsilon L) & \text{if } \varepsilon \leq \hat{\varepsilon}_S, \\ \alpha(1-\alpha)(2\rho-1)(\theta_h - \theta_l)L_c + K_c & \text{if } \hat{\varepsilon}_S < \varepsilon \leq \hat{\varepsilon}, \\ \alpha(1-\alpha)(2\rho-1)(\theta_h - \theta_l)L_c & \text{if } \varepsilon > \hat{\varepsilon}; \end{cases}$$

3. the firm mixing between certification and no certification in the region of parameter space where both certification and no certification equilibria exist.

The derivation of equilibrium conditions for the complements case proceeds in the same manner as the proof of the substitutes case presented above.

Proof of Proposition 4

1. Follows directly from the comparison of the certification equilibrium conditions outlined in Proposition 1 and those described in the certification equilibrium analysis for complements case above.

2. If \bar{k}_c is the maximum cost for which the certification equilibrium exists, given safety and effort are complements

$$\frac{\partial \bar{k}_c}{\partial \varepsilon} = \begin{cases} -\frac{\alpha(1-\alpha)(2\rho-1)(\theta_h - \theta_l)L}{\alpha(1-\rho) + (1-\alpha)\rho} < 0 & \text{if } \varepsilon \leq \hat{\varepsilon}_S, \\ L \frac{(\alpha\rho + (1-\alpha)(1-\rho))[\alpha(1-\rho)\theta_h + (1-\alpha)\rho\theta_l]}{\alpha(1-\rho) + (1-\alpha)\rho} > 0 & \text{if } \hat{\varepsilon}_S < \varepsilon \leq \hat{\varepsilon}_{NS}, \\ 0 & \text{if } \varepsilon > \hat{\varepsilon}_{NS}. \end{cases}$$

Welfare Implications

First, we consider the welfare implications in the basic model. If there is no certification, the firm sets price $p_{NC} = v - [\alpha(1-\theta_h) + (1-\alpha)(1-\theta_l)](L - L_f)$ to extract the entire consumer surplus. The firm makes a transfer L_f to the consumer in the case of an accident. Therefore, welfare W_{NC} is given by

$$W_{NC} = v - [\alpha(1-\theta_h) + (1-\alpha)(1-\theta_l)]L.$$

Using equilibrium firm profits given in the proof of Proposition 1, we can write the welfare if the firm seeks certification as

$$W_C = v - [\alpha(1-\theta_h) + (1-\alpha)(1-\theta_l)]L - k.$$

Since the change in welfare, $\Delta W \equiv W_C - W_{NC} < 0$, certification leads to reduction in welfare in the case of basic model. Next, consider the model with consumer moral hazard presented in Section 3.1. Safety and effort are substitutes. The change in welfare ΔW is calculated using firm profits and expected utility given in the proof of equilibrium. We get

$$\Delta W = \begin{cases} [\alpha(1-\rho)(1-\theta_h) + (1-\alpha)\rho(1-\theta_l)]\varepsilon L - [\alpha(1-\rho) + (1-\alpha)\rho]k & \text{if } \tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}, \\ -[\alpha\rho(1-\theta_h) + (1-\alpha)(1-\rho)(1-\theta_l)]\varepsilon L + [\alpha\rho + (1-\alpha)(1-\rho)]k & \text{if } \tilde{\varepsilon} < \varepsilon \leq \tilde{\varepsilon}_S, \\ -k & \text{otherwise.} \end{cases}$$

Similarly, for the model (presented in Section 3.2) in which safety and effort are considered complements, we get

$$\Delta W = \begin{cases} [\alpha\rho\theta_h + (1-\alpha)(1-\rho)\theta_l]\varepsilon L - [\alpha\rho + (1-\alpha)(1-\rho)]k & \text{if } \hat{\varepsilon}_S < \varepsilon \leq \hat{\varepsilon}, \\ -[\alpha(1-\rho)\theta_h + (1-\alpha)\rho\theta_l]\varepsilon L + [\alpha(1-\rho) + (1-\alpha)\rho]k & \text{if } \hat{\varepsilon} < \varepsilon \leq \hat{\varepsilon}_{NS}, \\ -k & \text{otherwise.} \end{cases}$$

Continuous Effort

Suppose safety and effort are substitutes. If the firm does not seek certification, and if consumer beliefs are consistent, then in this case, the consumers' expected utility can be written as

$$U_{NC} = v - p_{NC} - [\alpha(1-\theta_h) + (1-\alpha)(1-\theta_l)] \cdot [L(1 + \varepsilon - \varepsilon\varepsilon) - L_f] - \frac{1}{2}\tau\varepsilon^2.$$

Consumers choose effort e to maximize their expected utility. Therefore,

$$e_{NC} = \frac{[\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L\varepsilon}{\tau}$$

Using the above expression, we calculate the threshold $\tilde{\varepsilon}$ beyond which the consumer uses the product with full care ($e = 1$):

$$\tilde{\varepsilon} = \frac{\tau}{[\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L}$$

Similarly, we can derive the expressions for $\tilde{\varepsilon}_S$ and $\tilde{\varepsilon}_{NS}$ as

$$\tilde{\varepsilon}_S = \frac{[\alpha\rho + (1 - \alpha)(1 - \rho)]\tau}{[\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]L'}$$

$$\tilde{\varepsilon}_{NS} = \frac{[\alpha(1 - \rho) + (1 - \alpha)\rho]\tau}{[\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]L'}$$

Given $\alpha(1 - \rho)/(\alpha(1 - \rho) + (1 - \alpha)\rho) < \alpha < \alpha\rho/(\alpha\rho + (1 - \alpha)(1 - \rho))$, we get

$$\tilde{\varepsilon}_{NS} < \tilde{\varepsilon} < \tilde{\varepsilon}_S$$

Similar to the case of discrete effort levels described above, we can calculate the expected profits π_C for the certification equilibrium and the profits π_D if the firm deviates to not seeking certification as

$$\pi_C = [\alpha\rho + (1 - \alpha)(1 - \rho)]p_S + [\alpha(1 - \rho) + (1 - \alpha)\rho]p_{NS} - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L_f - k,$$

$$\pi_D = p_{NS} - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L_f.$$

Therefore, in a PBE the firm seeks certification if

$$k \leq [\alpha\rho + (1 - \alpha)(1 - \rho)](p_S - p_{NS}),$$

where p_S and p_{NS} are equilibrium prices set by the firm corresponding to granted and denied certification outcomes. The firm sets these prices taking consumers' equilibrium beliefs and their corresponding utility maximizing effort into account.

$$p_S = v - \left[\frac{\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)}{\alpha\rho + (1 - \alpha)(1 - \rho)} \right] \cdot L(1 + \varepsilon - \varepsilon e_S) - \frac{1}{2} \tau e_S^2,$$

$$p_{NS} = v - \left[\frac{\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)}{\alpha(1 - \rho) + (1 - \alpha)\rho} \right] \cdot L(1 + \varepsilon - \varepsilon e_{NS}) - \frac{1}{2} \tau e_{NS}^2,$$

where $e_S = ([\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]L\varepsilon)/([\alpha\rho + (1 - \alpha)(1 - \rho)]\tau)$ if $\varepsilon < \tilde{\varepsilon}_S$, and 1 otherwise; and $e_{NS} = ([\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]L\varepsilon)/([\alpha(1 - \rho) + (1 - \alpha)\rho]\tau)$ if $\varepsilon < \tilde{\varepsilon}_{NS}$, and 1 otherwise.

If \bar{k}_S is the maximum cost for which the certification equilibrium exists, \bar{k}_S first increases and then decreases with ε if $\varepsilon < \tilde{\varepsilon}_{NS}$, decreases with ε if $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S$, and does not depend on ε if $\varepsilon > \tilde{\varepsilon}_S$. The proof for the complement case proceeds in exactly the same manner as above and is therefore omitted.

Alternative Product Liability Assignment Rules

Since the proofs for different product liability assignment rules proceed in exactly the same manner as the proofs for Propositions 2 and 3 presented above, we only summarize the main results here.

(1) *Strict Liability*. First, consider that safety and effort are substitutes. The thresholds $\tilde{\varepsilon}_{NS}$, $\tilde{\varepsilon}$, and $\tilde{\varepsilon}_S$ for the substitutes case defined above in Section 3.1 are given by

$$\tilde{\varepsilon}_S \equiv \frac{\kappa[\alpha\rho + (1 - \alpha)(1 - \rho)]}{L_c[\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]'}$$

$$\tilde{\varepsilon} \equiv \frac{\kappa}{L_c[\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]'}$$

$$\tilde{\varepsilon}_{NS} \equiv \frac{\kappa[\alpha(1 - \rho) + (1 - \alpha)\rho]}{L_c[\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]'}$$

Given $\alpha(1 - \rho)/(\alpha(1 - \rho) + (1 - \alpha)\rho) < \alpha < \alpha\rho/(\alpha\rho + (1 - \alpha)(1 - \rho))$, we get $\tilde{\varepsilon}_{NS} < \tilde{\varepsilon} < \tilde{\varepsilon}_S$.

The firm's certification incentives are higher compared to the case without consumer moral hazard.

If \bar{k}_S is the maximum cost for which the certification equilibrium exists, given safety and effort are substitutes

$$\frac{\partial \bar{k}_S}{\partial \varepsilon} = \begin{cases} \frac{\alpha(1 - \alpha)(2\rho - 1)(\theta_h - \theta_l)L_c}{\alpha(1 - \rho) + (1 - \alpha)\rho} > 0 & \text{if } \varepsilon \leq \tilde{\varepsilon}_{NS}, \\ -L[\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)] < 0 & \text{if } \tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S, \\ 0 & \text{if } \varepsilon > \tilde{\varepsilon}_S. \end{cases}$$

Next, consider that safety and effort are complements. Thresholds $\hat{\varepsilon}_{NS}$, $\hat{\varepsilon}$, and $\hat{\varepsilon}_S$ for the complements case defined in Section 3.2 are given by

$$\hat{\varepsilon}_S \equiv \frac{\kappa[\alpha\rho + (1 - \alpha)(1 - \rho)]}{L_c[\alpha\rho\theta_h + (1 - \alpha)(1 - \rho)\theta_l]'}$$

$$\hat{\varepsilon} \equiv \frac{\kappa}{L_c[\alpha\theta_h + (1 - \alpha)\theta_l]'}$$

$$\hat{\varepsilon}_{NS} \equiv \frac{\kappa[\alpha(1 - \rho) + (1 - \alpha)\rho]}{L_c[\alpha(1 - \rho)\theta_h + (1 - \alpha)\rho\theta_l]'}$$

Given $\alpha(1 - \rho)/(\alpha(1 - \rho) + (1 - \alpha)\rho) < \alpha < \alpha\rho/(\alpha\rho + (1 - \alpha)(1 - \rho))$, we get $\hat{\varepsilon}_S < \hat{\varepsilon} < \hat{\varepsilon}_{NS}$.

The firm's certification incentives are lower compared to the case without consumer moral hazard.

If \bar{k}_C is the maximum cost for which the certification equilibrium exists, given safety and effort are complements

$$\frac{\partial \bar{k}_C}{\partial \varepsilon} = \begin{cases} -\frac{\alpha(1 - \alpha)(2\rho - 1)(\theta_h - \theta_l)L_c}{\alpha(1 - \rho) + (1 - \alpha)\rho} < 0 & \text{if } \varepsilon \leq \hat{\varepsilon}_S, \\ L_c \frac{(\alpha\rho + (1 - \alpha)(1 - \rho))[\alpha(1 - \rho)\theta_h + (1 - \alpha)\rho\theta_l]}{\alpha(1 - \rho) + (1 - \alpha)\rho} + L_f[\alpha\rho\theta_h + (1 - \alpha)(1 - \rho)\theta_l] > 0 & \text{if } \hat{\varepsilon}_S < \varepsilon \leq \hat{\varepsilon}_{NS}, \\ 0 & \text{if } \varepsilon > \hat{\varepsilon}_{NS}. \end{cases}$$

(2) *Contributory Negligence*. If safety and effort are substitutes, the thresholds $\tilde{\varepsilon}_{NS}$, $\tilde{\varepsilon}$, and $\tilde{\varepsilon}_S$ are given by

$$\tilde{\varepsilon}_S \equiv \frac{\kappa[\alpha\rho + (1 - \alpha)(1 - \rho)] - [\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]L_f}{[\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]L}$$

$$\tilde{\varepsilon} \equiv \frac{\kappa - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L_f}{[\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L},$$

$$\tilde{\varepsilon}_{NS} \equiv \frac{\kappa[\alpha(1 - \rho) + (1 - \alpha)\rho] - [\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]L_f}{[\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]L}.$$

Given $\alpha(1 - \rho)/(\alpha(1 - \rho) + (1 - \alpha)\rho) < \alpha < \alpha\rho/(\alpha\rho + (1 - \alpha)(1 - \rho))$, we get $\tilde{\varepsilon}_{NS} < \tilde{\varepsilon} < \tilde{\varepsilon}_S$.

The firm's certification incentives are higher compared to the case without consumer moral hazard.

If \bar{k}_s is the maximum cost for which the certification equilibrium exists, given safety and effort are substitutes

$$\frac{\partial \bar{k}_s}{\partial \varepsilon} = \begin{cases} \frac{\alpha(1 - \alpha)(2\rho - 1)(\theta_h - \theta_l)L_c}{\alpha(1 - \rho) + (1 - \alpha)\rho} > 0 & \text{if } \varepsilon \leq \tilde{\varepsilon}_{NS}, \\ -L[\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)] < 0 & \text{if } \tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S, \\ 0 & \text{if } \varepsilon > \tilde{\varepsilon}_S. \end{cases}$$

Next, consider that safety and effort are complements. The thresholds $\hat{\varepsilon}_{NS}$, $\hat{\varepsilon}$, and $\hat{\varepsilon}_S$ are given by

$$\hat{\varepsilon}_S \equiv \frac{\kappa[\alpha\rho + (1 - \alpha)(1 - \rho)] - [\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]L_f}{[\alpha\rho\theta_h + (1 - \alpha)(1 - \rho)\theta_l]L},$$

$$\hat{\varepsilon} \equiv \frac{\kappa - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L_f}{[\alpha\theta_h + (1 - \alpha)\theta_l]L},$$

$$\hat{\varepsilon}_{NS} \equiv \frac{\kappa[\alpha(1 - \rho) + (1 - \alpha)\rho] - [\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]L_f}{[\alpha(1 - \rho)\theta_h + (1 - \alpha)\rho\theta_l]L}.$$

Given $\alpha(1 - \rho)/(\alpha(1 - \rho) + (1 - \alpha)\rho) < \alpha < \alpha\rho/(\alpha\rho + (1 - \alpha)(1 - \rho))$, we get $\hat{\varepsilon}_S < \hat{\varepsilon} < \hat{\varepsilon}_{NS}$.

Also, the firm's certification incentives are lower compared to the case without consumer moral hazard.

If \bar{k}_c is the maximum cost for which the certification equilibrium exists, it is straightforward to show that

$$\frac{\partial \bar{k}_c}{\partial \varepsilon} = \begin{cases} -\frac{\alpha(1 - \alpha)(2\rho - 1)(\theta_h - \theta_l)L}{\alpha(1 - \rho) + (1 - \alpha)\rho} < 0 & \text{if } \varepsilon \leq \hat{\varepsilon}_S, \\ L \frac{(\alpha\rho + (1 - \alpha)(1 - \rho))[\alpha(1 - \rho)\theta_h + (1 - \alpha)\rho\theta_l]}{\alpha(1 - \rho) + (1 - \alpha)\rho} > 0 & \text{if } \hat{\varepsilon}_S < \varepsilon \leq \hat{\varepsilon}_{NS}, \\ 0 & \text{if } \varepsilon > \hat{\varepsilon}_{NS}. \end{cases}$$

When the Certification Decision Can Be Inferred from Prices

Consider the basic model described in Section 2, and assume that the consumers' valuation for the product is low enough ($v < ((\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l))/(\alpha(1 - \rho) + (1 - \alpha)\rho))L$) that if the firm is denied certification along the equilibrium path, the firm finds selling at price p_{NS} unprofitable. The above condition ensures that in the case when the firm is denied certification, it does not sell to consumers even if consumers believe the firm deviated to not seeking certification. However, the valuation is large enough ($v > ([\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]L - [\alpha(1 - \alpha)(2\rho - 1)(\theta_h - \theta_l)]L_f)/(\alpha(1 - \rho) + (1 - \alpha)\rho)$) that the firm is willing to sell to consumers at the same price if it deviates to not seeking certification. Therefore, if the consumers observe the firm

selling the product at price p_{NS} , they rationally infer that the firm deviated to not seeking certification.

Consider the candidate equilibrium in which the firm seeks certification. The firm sets price p_S if it is granted certification and $p_{NS} + \varepsilon$ if it is denied certification. If consumers observe the seal and the associated price p_S , they buy the product. However, if they do not observe the seal and they see a price higher than p_{NS} , they do not buy the product. Therefore, the firm's expected profits for certification equilibrium can be written as

$$\pi_C = [\alpha\rho + (1 - \alpha)(1 - \rho)]p_S - [\alpha\rho(1 - \theta_h) + (1 - \alpha)(1 - \rho)(1 - \theta_l)]L_f - k.$$

The firm is willing to sell at price p_{NS} if it deviates to not seeking certification. The consumers believe that the firm did not seek certification. If the firm deviates to not seeking certification and sets price at p_{NS} , the profits of the firm are given by

$$\pi_D = p_{NS} - [\alpha(1 - \theta_h) + (1 - \alpha)(1 - \theta_l)]L_f.$$

Therefore, in a PBE the firm seeks certification only if

$$k \leq \frac{\alpha(1 - \alpha)(2\rho - 1)(\theta_h - \theta_l)L_c}{\alpha(1 - \rho) + (1 - \alpha)\rho} - [\alpha(1 - \rho) + (1 - \alpha)\rho]v + [\alpha(1 - \rho)(1 - \theta_h) + (1 - \alpha)\rho(1 - \theta_l)]L.$$

In this case, an additional incentive for certification is created because of the firm's option of not selling the product when the firm is denied certification.

Now, we consider the presence of consumer moral hazard starting with the substitutes case. Since the proof follows the same strategy as the one presented above, we only summarize the main findings here. The result about additional incentives due to the option of not selling the product when the firm is denied certification continues to hold in the model with consumer moral hazard as well. A comparison of π_C and π_D in different ranges of the effectiveness ε of consumers' effort reveals a nonmonotonic effect of ε on the firm's incentives to seek certification. The incentive for certification first increases (if $\varepsilon \leq \tilde{\varepsilon}_{NS}$), then decreases (if $\tilde{\varepsilon}_{NS} < \varepsilon \leq \tilde{\varepsilon}_S$), and finally remains unchanged (if $\varepsilon > \tilde{\varepsilon}_S$) with increase in ε . Therefore, results presented in Section 3.1 are robust to this extension.

If safety and effort are complements, the presence of moral hazard acts to reduce the firm's incentive to seek certification. However, the option of not selling the product when the firm is denied certification creates incentives for certification. The firm's incentive to seek certification changes nonmonotonically with ε as described in Proposition 4 unless the probability with which the firm is denied certification is sufficiently large. In this case, the incentive for certification increases with ε in its entire range.

Endnotes

¹ For example, an NSF International study conducted in 2013 found that 44% of consumers prefer products that are independently tested and certified.

² For example, even if the court requires the firm to compensate for all proven physical losses, consumers may still suffer from pain/trauma

and the burden of legal fees. Under the American Rule, which is the default rule controlling assessment of attorney's fees in the United States, each party pays its own legal fees.

³In related work, Polinsky and Rogerson (1983) investigates how the optimal liability rules depend on the market power of the sellers when consumers underestimate the losses from the accident.

⁴There is also a literature on disclosure in the context of distribution relationships. For example, Guo (2009) examines a manufacturer's choice of quality disclosure format between direct disclosure to consumers and indirect disclosure through downstream retailers in a distribution channel. Sun (2015) examines the effect of the channel structure on the manufacturer's incentive to disclose product-match information to the consumers.

⁵Note that if $\rho < 0.5$, the firm would be better off without a certification sticker and therefore would always choose no certification. If $\rho = 0.5$, consumers would ignore the certification outcome. Therefore, the relevant case for our analysis is $\rho > 0.5$, which ensures that the certification provides an informative signal of safety.

⁶It is important to note that in the intermediate range, the consumers equilibrium beliefs λ is consistent with the firm's certification decision.

⁷A mixed strategy equilibrium also exists (as derived in the appendix) in the range where both certification and no certification equilibrium exists where the firm mixes between certification and no certification. Consistent with intuition, in this equilibrium the probability of choosing no certification is increasing in the cost k .

⁸Section 4.1 presents an extension of this model in which the effort chosen by the consumer is continuous and where the cost of effort is smoothly increasing and convex.

⁹Consumer effort and product safety may be independent as well. However, in that case the equilibria are as in Proposition 1. This is because the consumer's choice of effort does not depend on her beliefs about the firm type. Certification plays a role by changing the beliefs of the consumer about the firm type. Since beliefs do not affect the choice of consumer effort, the equilibrium does not depend on the effort choice.

¹⁰In Section 4.2, we investigate other possible liability assignments rules (both "strict liability" and "contributory negligence") and show that the results presented in the main model are robust to these alternative liability assignment rules.

¹¹As an example, in the famous *Liebeck v. McDonald's Restaurants, P.T.S., Inc.* (No. D-202 CV-93-02419, 1995 WL 360309) case (also known as "the hot coffee lawsuit"), the jury in its August 18, 1994, verdict awarded Liebeck US\$200,000 in compensatory damages but then reduced it to US\$160,000 using the law of comparative negligence to reflect the 20% fault that was assessed of Liebeck in causing the accident.

¹²http://www.amazon.com/fire-extinguisher/b/ref=dp_brw_link?ie=UTF8&node=13400621, accessed September 26, 2015.

References

Cooper R, Ross TW (1985) Product warranties and double moral hazard. *RAND J. Econom.* 16(1):103–113.

- Daughety AF, Reinganum JF (2005) Secrecy and safety. *Amer. Econom. Rev.* 95(4):1074–1091.
- Daughety AF, Reinganum JF (2008) Communicating quality: A unified model of disclosure and signalling. *RAND J. Econom.* 39(4):973–989.
- Desai PS, Srinivasan K (1995) Demand signalling under unobservable effort in franchising: Linear and nonlinear price contracts. *Management Sci.* 41(10):1608–1623.
- Gal-Or E (1989) Warranties as a signal of quality. *Canadian J. Econom.* 22(1):50–61.
- Glannon JW (2010) *The Law of Torts*, 4th ed. (Aspen Publishers, New York).
- Grossman SJ (1981) The informational role of warranties and private disclosure about product quality. *J. Law Econom.* 24(3):461–483.
- Guo L (2009) Quality disclosure formats in a distribution channel. *Management Sci.* 55(9):1513–1526.
- Guo L, Zhao Y (2009) Voluntary quality disclosure and market interaction. *Marketing Sci.* 28(3):488–501.
- Iyer G, Kuksov D (2010) Consumer feelings and equilibrium product quality. *J. Econom. Management Strategy* 19(1):137–168.
- Levitt SD (2006) The difference between "theoretically possible" and "important." *Freakonomics* (blog) (December 9), <http://freakonomics.com/2006/12/09/the-difference-between-theoretically-possible-and-important/>.
- Levitt SD, Porter J (2001) Sample selection in the estimation of air bag and seat belt effectiveness. *Rev. Econom. Statist.* 83(4):603–615.
- Lutz NA (1989) Warranties as signals under consumer moral hazard. *RAND J. Econom.* 20(2):239–255.
- Milgrom PR (1981) Good news and bad news: Representation theorems and applications. *Bell J. Econom.* 12(2):380–391.
- Milgrom P, Roberts J (1986) Price and advertising signals of product quality. *J. Political Econom.* 94(4):796–821.
- National Safety Council (2013) *National Safety Council Injury Facts, 2013 Edition* (National Safety Council, Itasca, IL).
- Oi WY (1973) The economics of product safety. *Bell J. Econom. Management Sci.* 4(1):3–28.
- Padmanabhan V, Rao RC (1993) Warranty policy and extended service contracts: Theory and an application to automobiles. *Marketing Sci.* 12(3):230–247.
- Padmanabhan V, Rajiv S, Srinivasan K (1997) New products, upgrades, and new releases: A rationale for sequential product introduction. *J. Marketing Res.* 34(4):456–472.
- Peltzman S (1975) The effects of automobile safety regulation. *J. Political Econom.* 83(4):677–725.
- Png IPL (1987) Litigation, liability, and incentives for care. *J. Public Econom.* 34(1):61–85.
- Polinsky AM, Rogerson WP (1983) Products liability, consumer misperceptions, and market power. *Bell J. Econom.* 14(2):581–589.
- Polinsky AM, Rubinfeld DL (1988) The deterrent effects of settlements and trials. *Internat. Rev. Law Econom.* 8(1):109–116.
- Spence M (1977) Consumer misperceptions, product failure and producer liability. *Rev. Econom. Stud.* 44(3):561–572.
- Sun M (2015) Product match disclosure in a distribution channel. Working paper, Boston University, Boston.
- Zhang J (2014) Policy and inference: The case of product labeling. Working paper, Massachusetts Institute of Technology, Cambridge.